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Biogas and ecological sanitation

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- German Biogas and Bioenergy Society GERBIO -
on behalf of
Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

FNBB e.V. / GERBIO

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Im Auftrag des:

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung

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Millennium development goals (MDGs)

⇒ **Achievement of poverty eradication and sustainable development by rapidly increasing access to basic requirements such as <u>clean water</u>, <u>sanitation</u>, energy, health care, food security and the protection of biodiversity**

⇒ **<u>Set target for water and sanitation</u>:**

To halve the proportion of people without access to safe drinking water and to adequate sanitation by 2015

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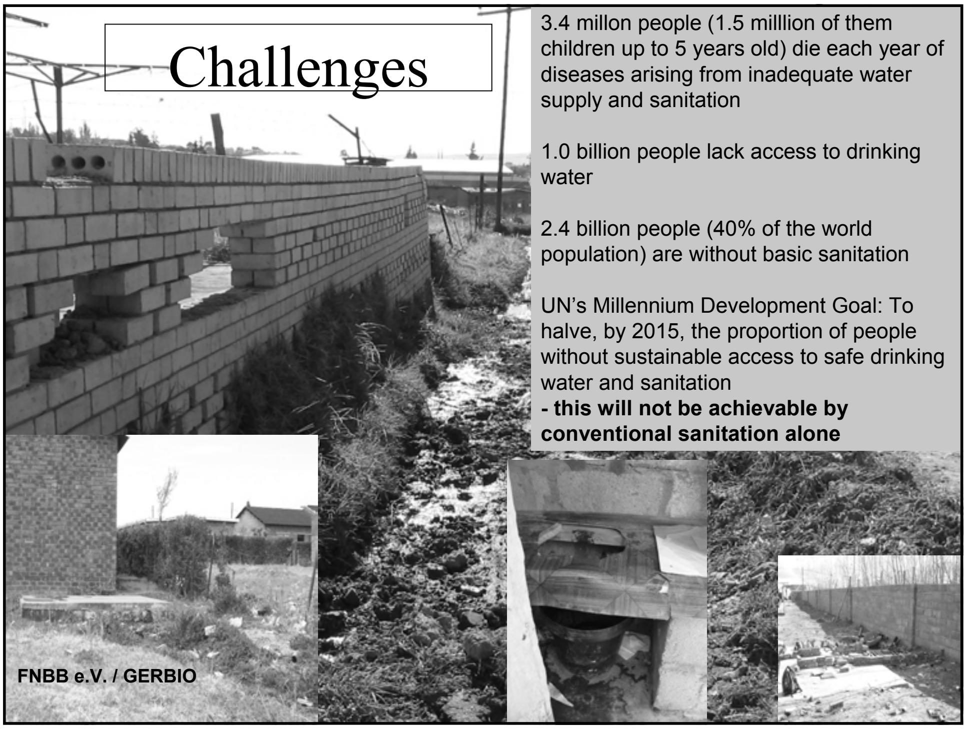
Challenges



3.4 millon people (1.5 milllion of them children up to 5 years old) die each year of diseases arising from inadequate water supply and sanitation

1.0 billion people lack access to drinking water

2.4 billion people (40% of the world population) are without basic sanitation

UN's Millennium Development Goal: To halve, by 2015, the proportion of people without sustainable access to safe drinking water and sanitation
- this will not be achievable by conventional sanitation alone

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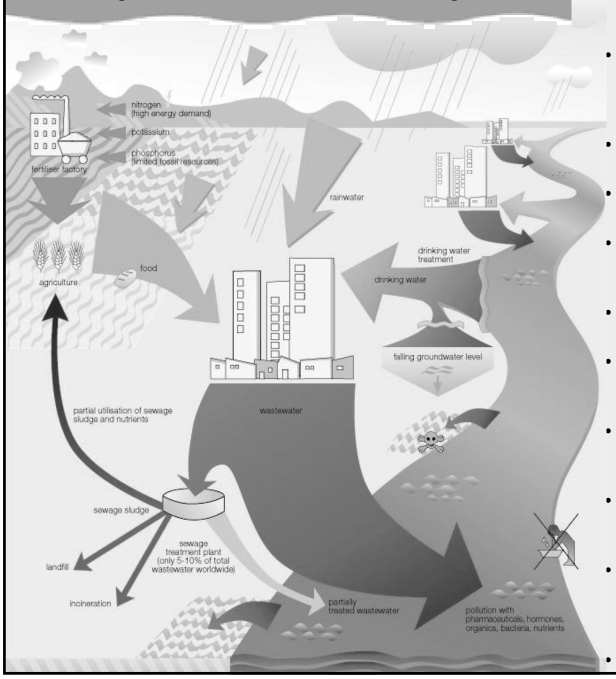
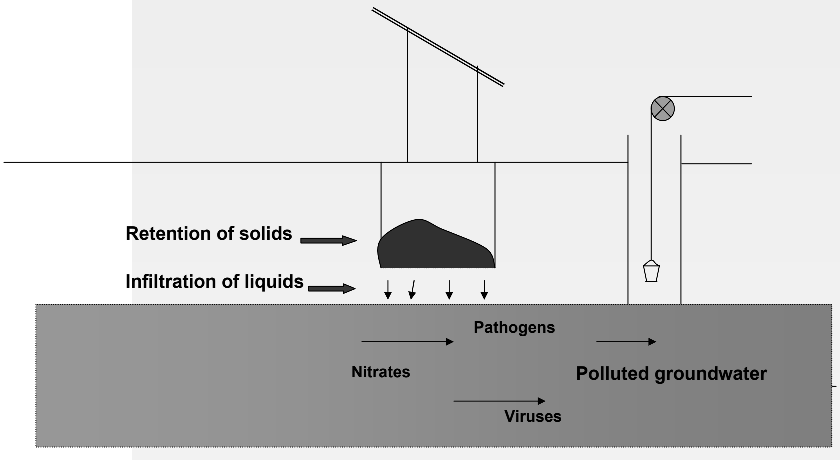
Shortcomings of conventional „flush and discharge“ sanitation



- Unsatisfactory purification or uncon-trolled discharge of more than 90 % of wastewater worldwide
- Pollution of waters by organics, nutrients, hazardous substances, pathogens, pharmaceutical residues, hormones, etc.
- Unbearable health risks and spread of disease
- Severe environmental damage and eutrophication of the water cycle
- Consumption of precious water for transport of waste (water carriage waste disposal system)
- High investment, energy, operating and maintenance costs
- Frequent subsidization of prosperous areas and neglect of poorer settlements
- Loss of valuable nutrients and trace elements contained in excrements due to discharge into waters
- Impoverishment of agricultural soils, increased dependence on chemical fertilizers
- Combined, central systems are predominant in organised waste-water disposal, resulting in problems with contaminated se-wage sludge
- **Linear end-of-pipe technology**

Shortcomings of conventional „drop and store“ sanitation



Phosphate

	Mine production 2001	Mine production 2002[e]	Reserves	Reserve base
United States	31,900	35,800	1,000,000	4,000,000
Australia	1,890	1,800	77,000	1,200,000
Brazil	4,700	4,700	330,000	370,000
Canada	800	1,000	25,000	200,000
China	21,000	21,000	6,600,000	13,000,000
Israel	3,510	3,500	180,000	800,000
Jordan	5,840	7,000	900,000	1,700,000
Morocco and Western Sahara	21,800	24,000	5,700,000	21,000,000
Russia	10,500	10,500	200,000	1,000,000
Senegal	1,700	1,500	50,000	160,000
South Africa	2,550	2,800	1,500,000	2,500,000
Syria	2,040	2,400	100,000	800,000
Togo	1,060	1,100	30,000	60,000
Tunisia	8,000	7,500	100,000	600,000
Other countries	8,710	8,000	1,000,000	2,000,000
World total (rounded)	126,000	133,000	17,000,000	50,000,000

- **World demand for phosphate fertilizers continues to expand in relation to increased world population and food requirements.**
- **For the period 2003-07, world phosphate consumption is forecasted to increase by 2.6% annually.**
- **Within about 60 years, all reserved phosphate are expected to be mined.**
- **Future conflicts on the access to phosphate are likely, due to the limited reserves and the concentration of significant minable resources in a very small number of countries.**

(US Geological survey, 2003)

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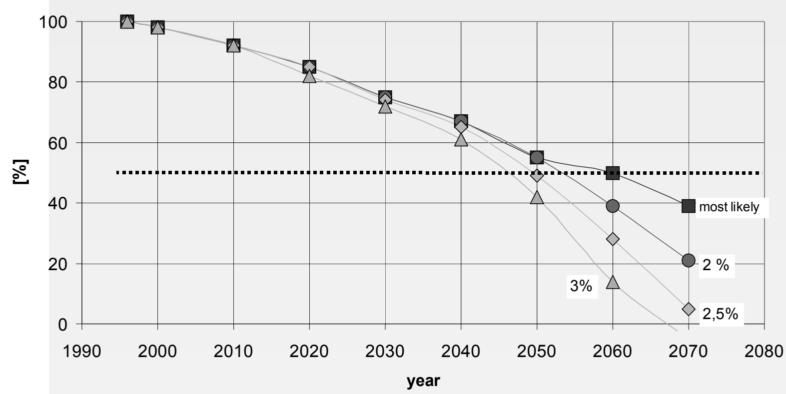
Limitación del fosforo

Lifetime of phosphate reserves at different scenarios

(parameter:yearly increase of phosphate consumption based on 7,000,000 t P_2O_5 reserves)



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Balance of the nutrient cycle:

In theory, one person can fertilize with his own ecosan recyclates an agricultural area, needed to feed him with vegetables, cereals and fruits.

Extension area for urine and faeces application from one adult person:

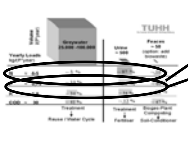
German law for fertilizer use / water shed protection

Maximum **N** (Nitrate): 150 kg/(ha*a)

Maximum **P** (Phosphorus): 25 kg/(ha*a)

$$4 \cdot \frac{10000}{150} = \underline{\underline{266 m^2}}$$

$$0{,}675 \cdot \frac{10000}{25} = \underline{\underline{270 m^2}}$$



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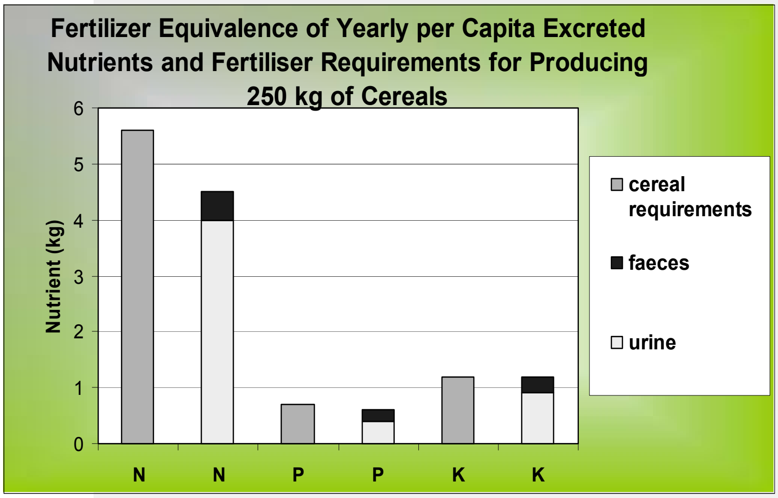
Fertilizer equivalent of human excreta



(Drangert, 1998)

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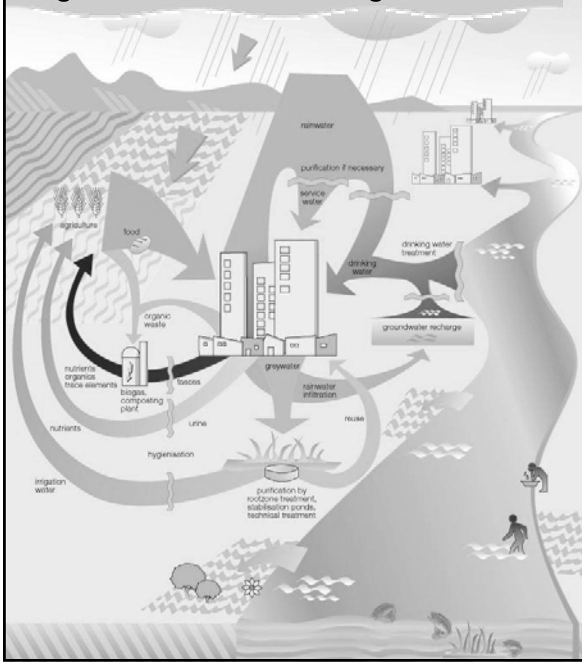
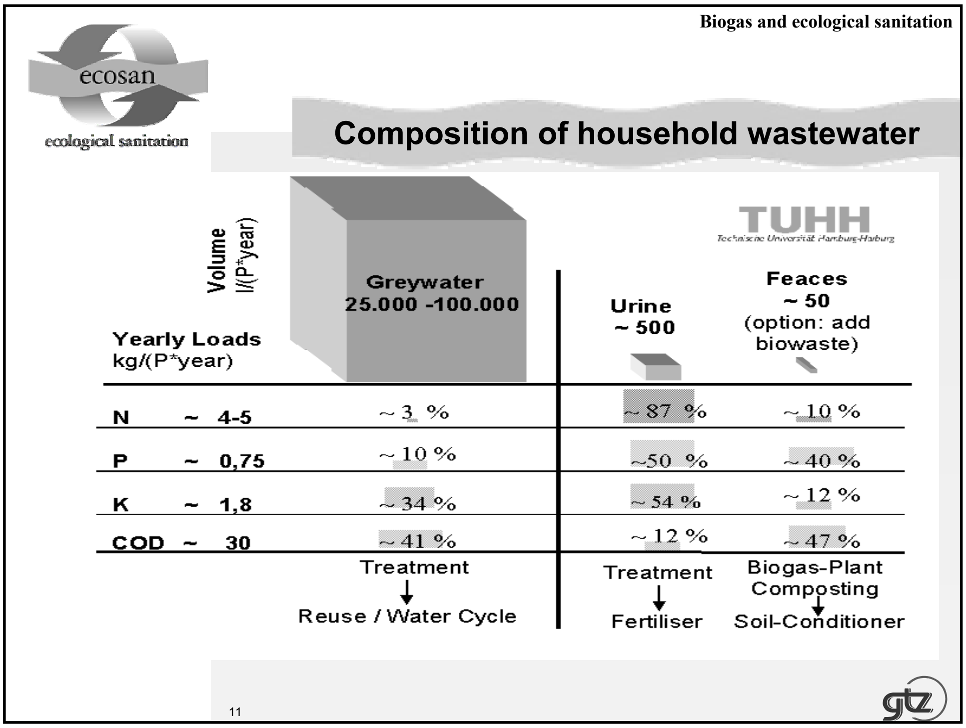
Biogas as the heart of ecological sanitation



- **Improvement of health** by minimizing the introduction of pathogens from human excrements into the water cycle
- **Promotion of recycling** by safe, hygienic recovery and use of nutrients, organics, trace elements, water and **energy**
- **Conservation of resources** through optimised water and energy consumption, substitution of chemical fertilisers, minimization of water pollution
- Preference for modular, decentralised partial-flow systems for more appropriate, energy and cost-efficient solutions
- Possibility to integrate on-plot systems into houses, increasing user-comfort and security for women and girls
- Preservation of soil fertility improving of agricultural productivity and, hence contribution to food security
- Promotion of a holistic, interdisciplinary approach (hygiene, water supply and sanitation, resource conservation, environmental protection, urban planning, agriculture, food-security, small business promotion, household energy etc)
- **Material flow cycle instead of disposal**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Composition of household wastewater
TUHH
Technische Universität Hamburg-Harburg
Volume
l/(P*year)
Greywater
25.000 -100.000
Urine
~ 500
Feaces
~ 50
(option: add biowaste)
Yearly Loads
kg/(P*year)
N ~ 4-5
P ~ 0,75
K ~ 1,8
COD ~ 30
~ 3 %
~ 10 %
~ 34 %
~ 41 %
~ 87 %
~50 %
~ 54 %
~ 12 %
~ 10 %
~ 40 %
~ 12 %
~ 47 %
Treatment
Reuse / Water Cycle
Treatment
Fertiliser
Biogas-Plant
Composting
Soil-Conditioner
11
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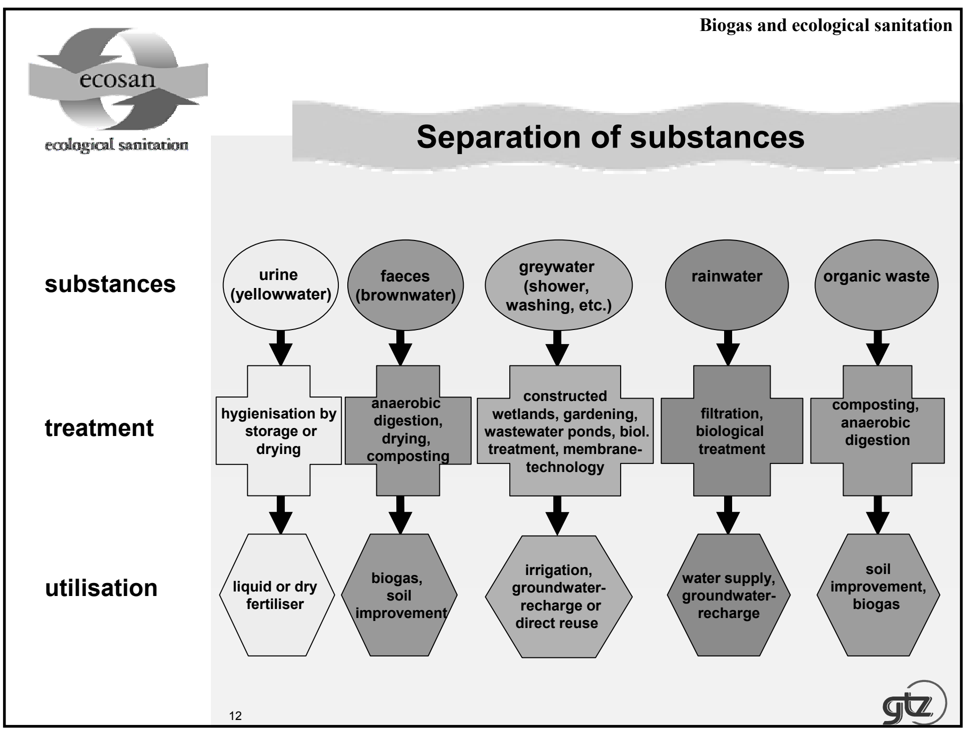
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Separation of substances
substances
treatment
utilisation
urine (yellowwater)
faeces (brownwater)
greywater (shower, washing, etc.)
rainwater
organic waste
hygienisation by storage or drying
anaerobic digestion, drying, composting
constructed wetlands, gardening, wastewater ponds, biol. treatment, membrane-technology
filtration, biological treatment
composting, anaerobic digestion
liquid or dry fertiliser
biogas, soil improvement
irrigation, groundwater-recharge or direct reuse
water supply, groundwater-recharge
soil improvement, biogas
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Characteristics of substances

fraction	characteristic
1. faeces	• hygienically critical • consists of organics, nutrients and trace elements • improves soil quality and increase its water retention capacity
2. urine	• less hygienically critical • contains the largest proportion of nutrients available to plants • may contain hormones or medical residues
3. greywater	• of no major hygienic concern • volumetrically the largest portion of wastewater • contains almost no nutrients (simplified treatment) • may contain spent washing powders etc.

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Agricultural utilisation of nutrients

Human faeces and urine can be utilised in agriculture under the following conditions:

- Proper pre-treatment (storage, drying, composting, anaerobic fermentation, heating, filtration, irradiation with UV etc.)
- Suitable „handling“ (with security measures)
- Limitation to specific vegetables and field crops, and to specific vegetation periods, depending on pre-treatment
- Regular sampling and hygiene control
- Respect of the crops nutrient needs (no over-fertilisation)

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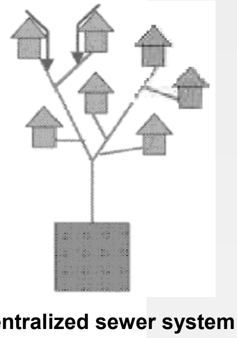
WHO guidelines for agricultural use of treated wastewater

Category	Use	Person / Group exposed	Nematodes [Eggs / kg]	Feacal coliforms [number / 100 g]
A	Application to field crop (used for raw food)	worker, consumer, public	</= 1	</= 1000
B	Application to field crop (for industrial use, feedstock, trees)	worker	</= 1	no suggested standard
C	Local application to field crop of cat. B, without contact to persons	none	not relevant	not relevant

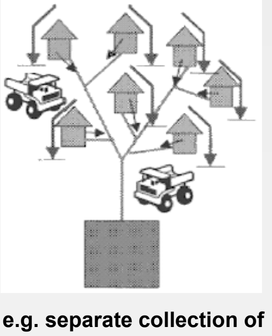
Centralized and decentralized system

Centralized



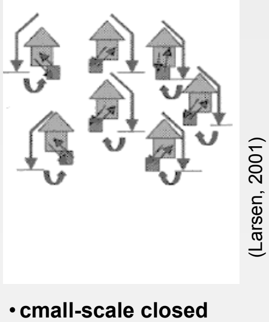
- centralized sewer system and treatment
- recovery of nutrients and water e.g. through reuse of wastewater

Partially decentralized



- e.g. separate collection of urine or blackwater
- centralized nutrient processing facility
- centralised greywater sewer systam and treatment

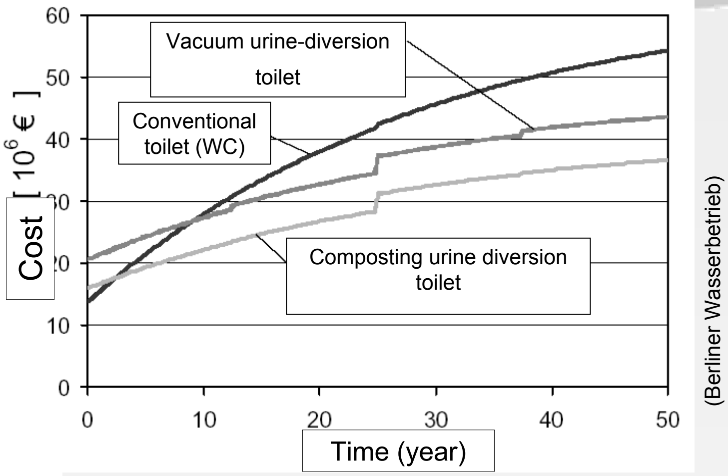
Fully decentralized



(Larsen, 2001)

- cmall-scale closed cycles of water and materials

Cost comparison: ecosan vs conventional



Projected costs for sanitation service for 5000 inhabitants, Germany

Biogas and ecological sanitation

examples of urine diverting toilets


China

DRY

waterless


GTZ,Mali


Wost-Man, Schweden

faeces without, urine with flush


Roediger, Germany

low-flush


Dubletten, Sweden

WET

waterless urinals

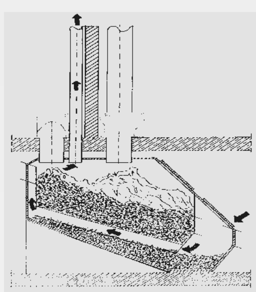
Mon Museum, Sweden

Lambertsmühle, Germany

vacuum urinal KfW-building, Germany

examples of composting toilets

Norway



Sweden

Germany

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examples of composting toilets


Japan, Bio-Lux **(Seiwa Denko Ltd)**

Several mixing mechanisms




Mixing chamber with sawdust

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examples of dehydrating toilets

Dehydrating toilet, China

Rear view of a dehydrating toilet, Mali

"Enviroloo", South Africa

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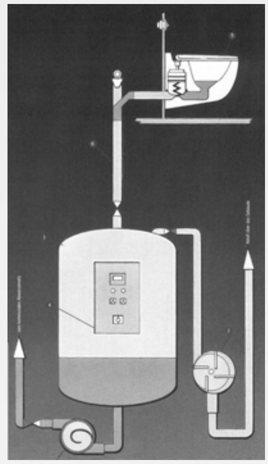
vacuum toilets

Vacuum toilet, Germany, Roediger GmbH



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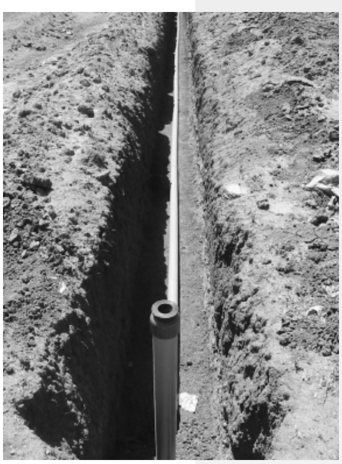
In-house, neighbourhood or central vacuum collection networks

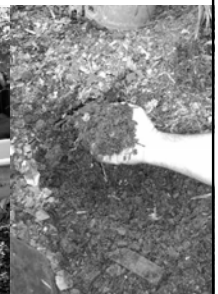


Shoshong,
Botswana

ecosan pilot projects

ecosan-study and reuse experiments in Havana, Cuba (supported by GTZ)

- Study of options for reuse of urine and faeces in existing urban agriculture in Havana

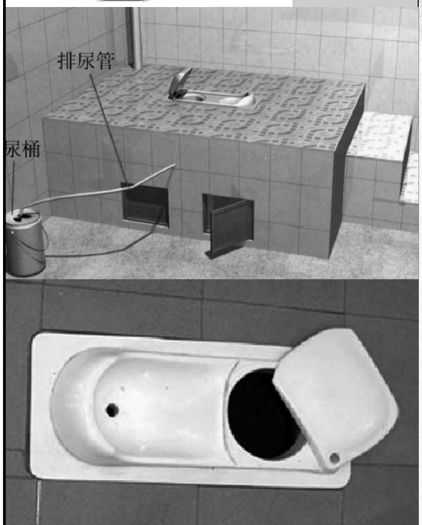


ecosan pilot projects

participatory development of ecosan solutions in Gibeon and Mariental, Namibia (supported by GTZ)

- Information, awareness building, situation and stakeholder analysis
- Participatory development of ecosan concepts
- Pilot and demonstration units (fixed and movable dehydration toilets with urine diversion)

ecosan dry toilet promotion in Guangxi-Province, China



Photos: Sandec, Text: Mi Hua

- Large ecosan project in the phase of up-scaling
  - 1997, pilot project funded by SIDA/Unicef, 70 ecosan (urine diverting dehydration toilets) built in pilot village, Dalu Village
  - 1998, 10,000 urine-diverting toilets were built in 200 ecosan villages in Guangxi
  - 2002, 100,000 ecosan toilets in Guangxi
  - 2003, 685,000 ecosan toilets in 17 provinces (Ministry of Public Health)
- Factors of success: cultural acceptance, political commitment, technical flexibility, low cost, income generation, pressure from water pollution and water scarcity, promotion and marketing

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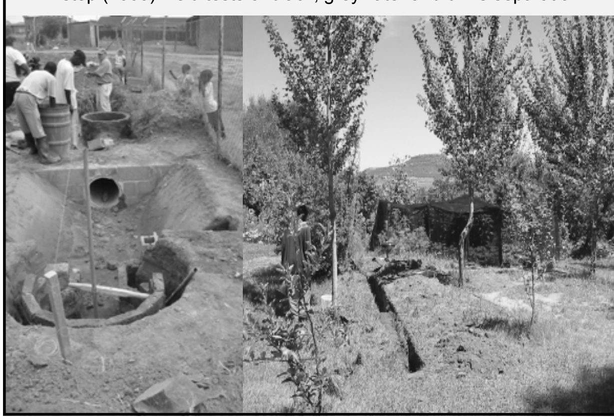
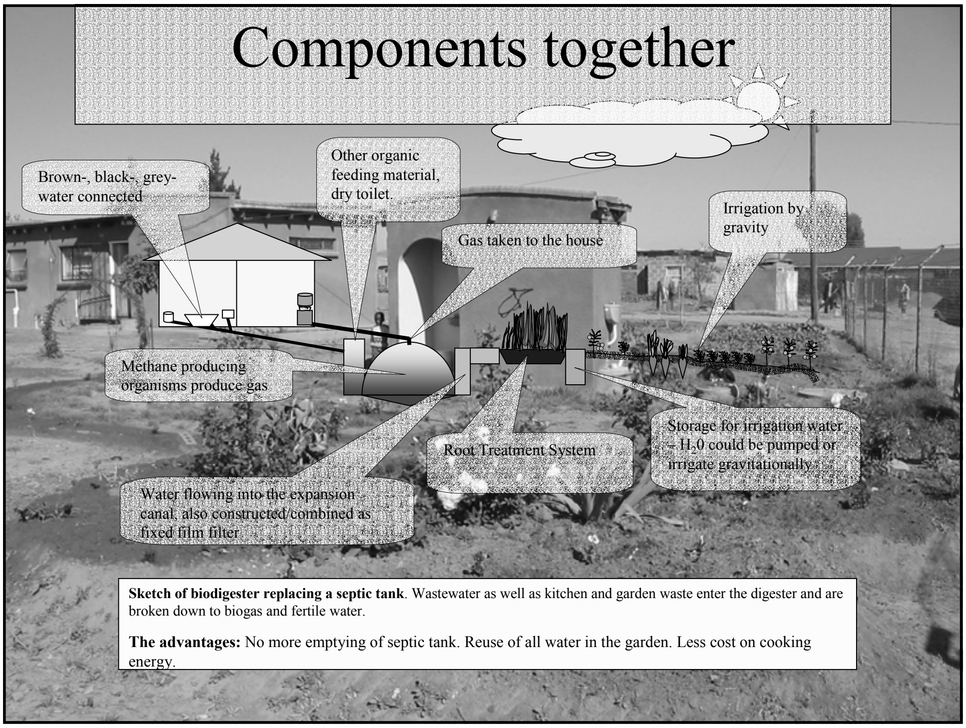
ecosan pilot projects supported by GTZ/DED

LESOTHO

- **Pilot demonstration of neighborhood centered waterborne closed loop system**

- 1st step (2002): small bore sewer grid for 8 houses, a biogas-septic tank unit, upflow filter based on recycled plastic bottles, wetland, 800m² vegetable and fruit garden, two household connections for the biogas as full cooking energy source
- 2nd step (2003): field tests of black, greywater and urine separation





Sketch of biodigester replacing a septic tank. Wastewater as well as kitchen and garden waste enter the digester and are broken down to biogas and fertile water.

The advantages: No more emptying of septic tank. Reuse of all water in the garden. Less cost on cooking energy.

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Running cost (-) or benefits (+) in Maluti per year (4 person household)

• Conventional septic tank	- 600
• Biodigester septic tank	+400
• Cheap pit latrine	- 50
• Sophisticated double vault VIP latrines	- 100
• Ecosan toilet with urine separation, utilizing compost and urine	+200
• Minimum urine separation set up, utilizing urine only	+ 30

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Recycling on household-level:

Biogas production from cattle dung and toilet waste

Use of energy and nutrient content

ecosan-example in Dhapasi, Nepal

Wastewater from Toilets	Small biogas reactor	Use of biogas for cooking
Dung from cattle	for 1 household	Use of slurry for garden fertilizing

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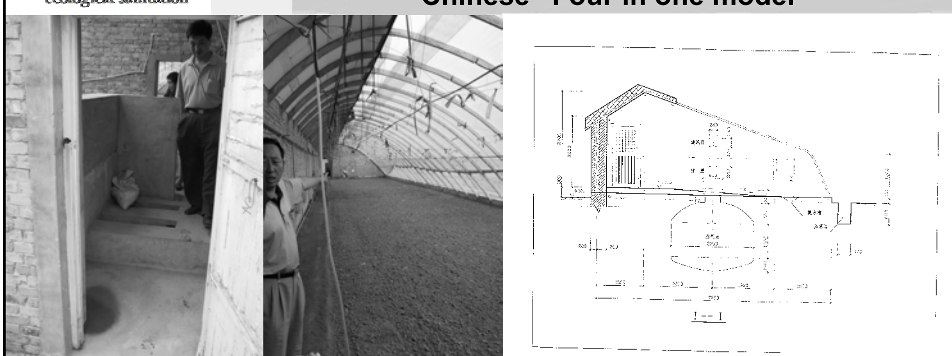
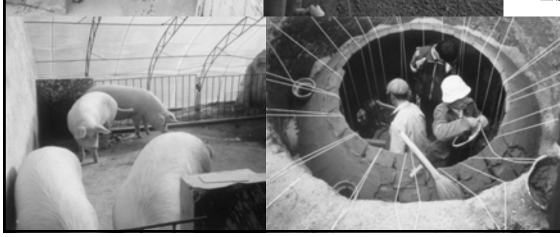
Chinese “Four in one model”





Pig – Toilet – Biogas – Vegetable

- combined with Greenhouse Production
- more than 160,000 times in peri urban areas of Megacities in Northern China
- Use of nutrients, organics, energy and carbon dioxyde

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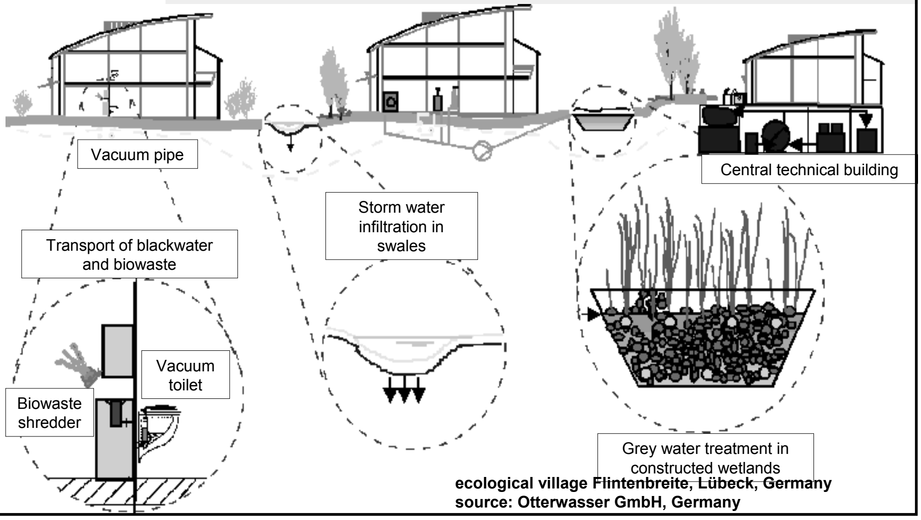
GERMANY

current ecosan pilot projects

- **An integrated ecological sanitation concept within an eco-settlement for 350 people in Lübeck – a comprehensive urban ecosan system**



ecological village Flintenbreite, Lübeck, Germany
source: Otterwasser GmbH, Germany

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current ecosan pilot projects

GERMANY

- **An integrated ecological sanitation concept within an eco-settlement for 350 people in Lübeck – a comprehensive urban ecosan system**

Vacuum station, sanitization tank and biogas treatment plant for the collection and anaerobic treatment of black water and bio waste

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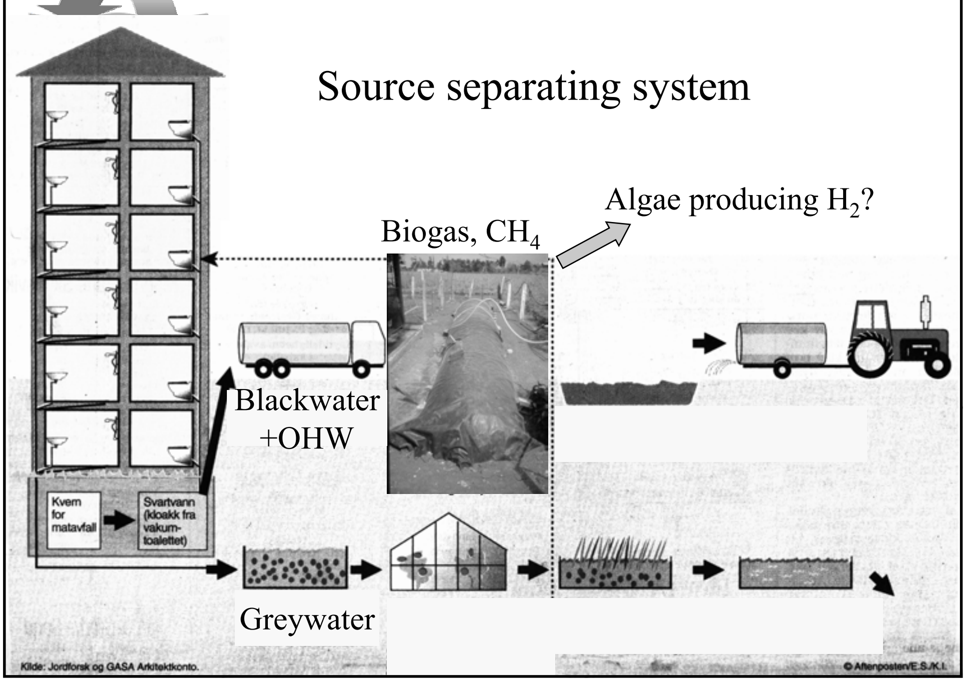
Source separating system



Biogas and ecological sanitation

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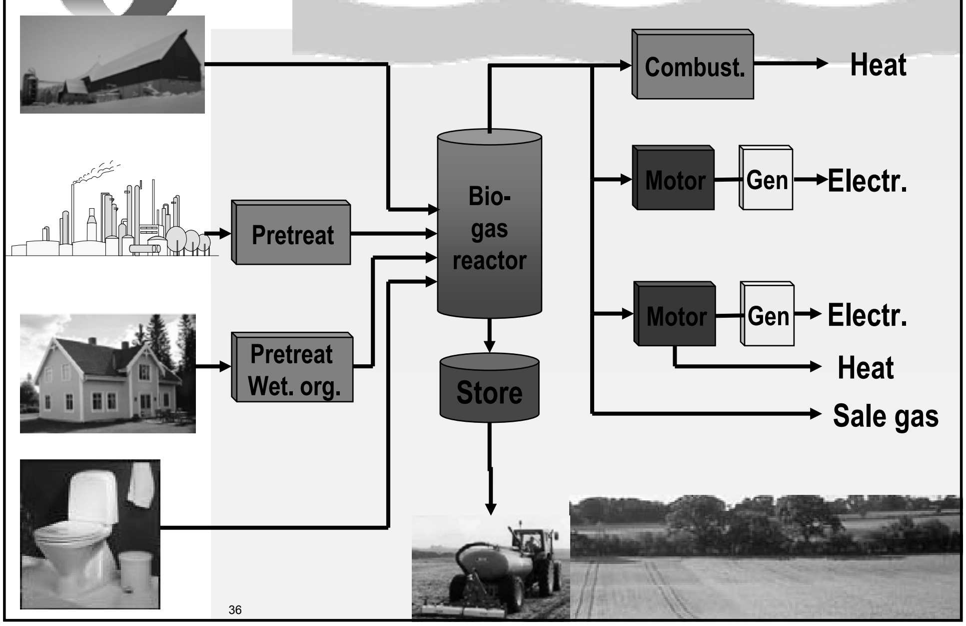
Mass flows in biogas production



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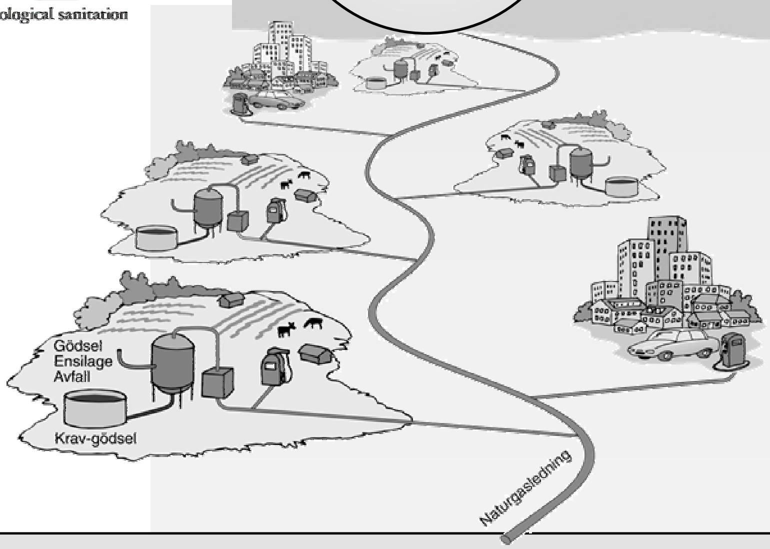
Biogas-Network-Grid



Trollhättans Stad

B I O G A S   T R O L L H Ä T T A N

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Earthworm treatment system

Earthworm treatment system (South Africa)

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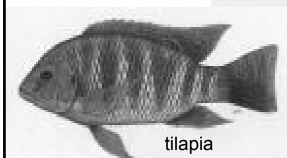
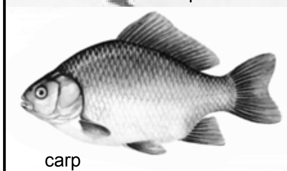
Aquaculture

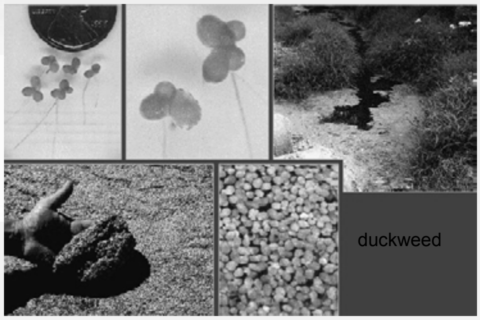
- Wastewater treatment by aquatic plants and fish with nutrient recycle by human consumption
- Offers high quality protein at low cost
- Predominantly in Asian countries
- Fish production of 1-6 tons/(ha·year) achieved



tilapia



carp



duckweed

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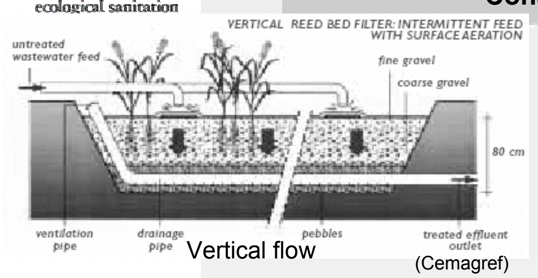
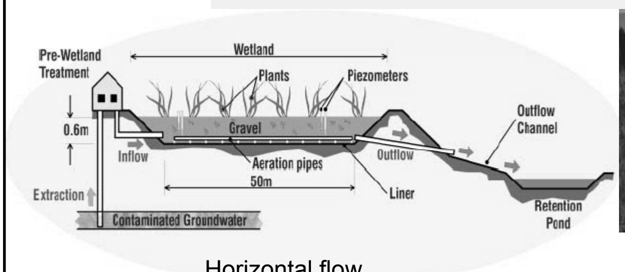
Constructed wetland



Vertical flow (Cemagref)

- Treatment of wastewater, or greywater
- Effective in the removal of BOD, TSS, pathogen, and nitrogen
- Effluent can be reused
- Aesthetically appealing



Horizontal flow

(Komex International Ltd.)

Stabilization pond/ lagoon

- Low cost technology, simple form of wastewater treatment

(Morel, 2002)

Wastewater treatment with biomass production

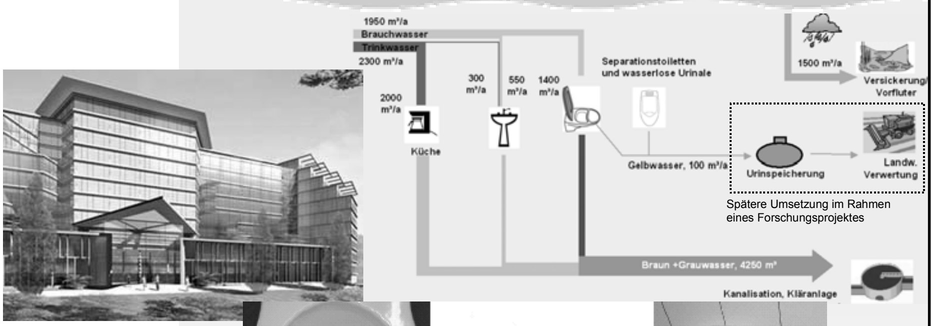
(EU-FAIR, 2003)

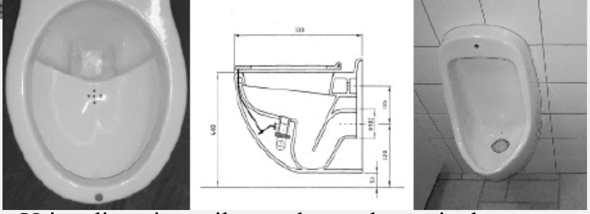
- Combined wastewater treatment and bio-fuel production from willow plantations (example in Sweden)
- Cost and energy effective.

"epuvalisation"

Epuvalisation - Nutrient recycling (Senegal)

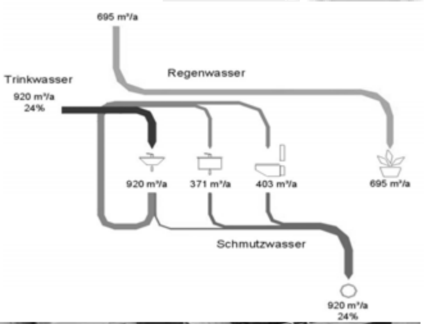
GTZ House 1 Renovations, Germany, 2004





Urine diversion toilets and waterless urinals

KFW building, Germany, 2003 with ecosan concept



1. Greywater recycling
2. Rainwater harvesting
3. Vacuum wastewater collection

Urine Storage

Storage tank, Lambertsmühle, Otterwasser GmbH

Storage tank, Gebers, Sweden

Storage tank, Agricultural area, Sweden

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Demystifiying Urine → Closing the Loop

Cash crops

In Sweden

Nopal cactus

In Mexico

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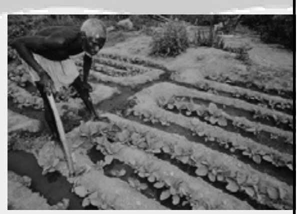
Agricultural reuse

Direct injection of liquid fertiliser

For irrigation purposes



In (urban) agriculture

Dried faeces (for soil amelioration)

Co-composting with organic household refuse

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Biofuels and conversion

	% dry matter	Gas prod	Combust
Manure	7 - 12	+ + +	-
Black (brown) water	0.5 - 2	+ +	- - -
Sludge	25 - 50	+ +	+ / -
Slaughter waste	40 - 60	+ + + +	+ + / - -
Wet organic waste	20 - 50	+	+ / -

Energy in wastewater per person per year (brown water)
75 – 130 kWh net energy output
NLH, 2003

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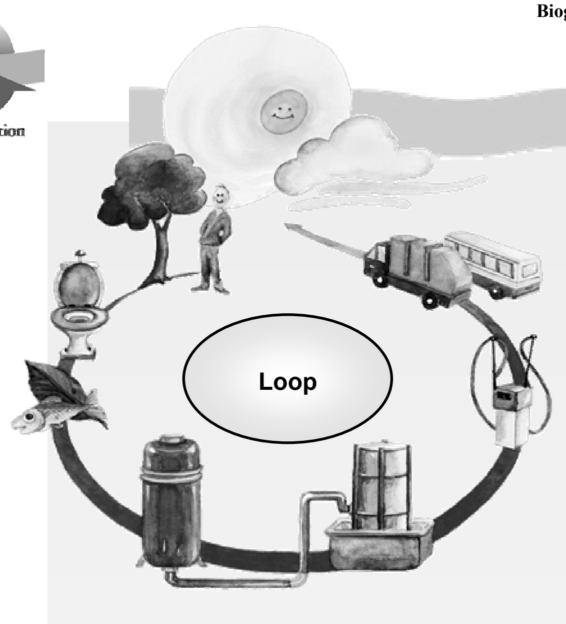

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Conclusion: ecosan = triple win

water → **protection of water resources through reduced consumption and less contamination**

agriculture → **higher agricultural yields through the recovery of nutrients**

hygiene → **minimisation of water-based infections**

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Thanks!!!

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