From waste water to a usable surface water

Practical aspects of sustainable water management

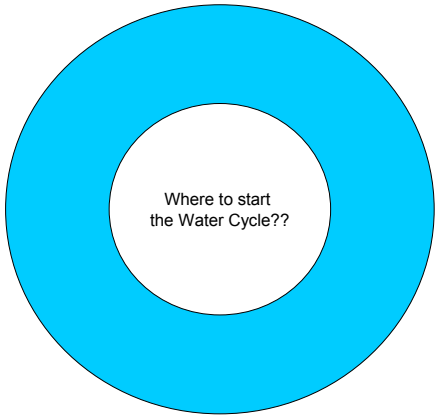
Saxion University Deventer

Env. Science & Technology, Civil Engineering en Urban and Regional Planning

Wednesday, 7 January 2009

Ruud Kampf

Researcher ecological engineering
Waternet Institute for Water Cycle Management, Research & Engineering
PO Box 94370, 1090 GJ Amsterdam, Netherlands
Guest worker Vrije Universiteit Amsterdam, Faculty of Earth and Life Sciences,
Department of Animal Ecology



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- Waternet: the first watercycle company in the Netherlands
- *Conclusions of this presentation*

Part 1:

- Waste water: get the water out of the waste?
- Effect of a discharge: biology of polluted surface water
- Waterharmonica: The Waterharmonica: the natural link between treated waste water and surface water
- Waterharmonica: practical aspects
- Biological filtration natural values → European Water Framework Directive
- European examples

Part 2:

- Nepal, Tanzania, Kenya
  - Polluter pays???
  - No money for waste water treatment?

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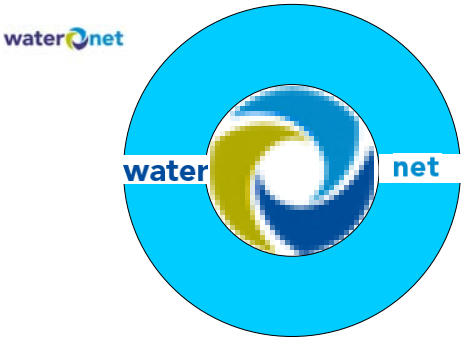
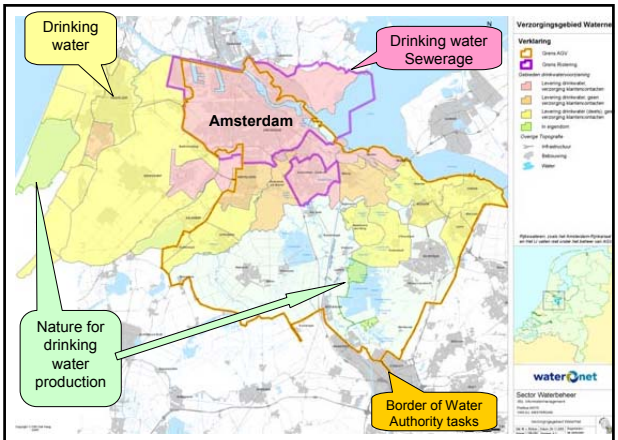


Vision en mission

the first company in the Netherlands that combines all water services responsible for drinking water, waste water, surface water and safety behind the dykes.

Waternet

- Water Authority for 1.2 million people
  - in "greater Amsterdam: 700 km^2
  - dikes, sluices, pumping stations, roads on dikes, etc
  - care of surface water system plus ground water
  - sewer systems, sewage treatment plants
- Drinking water provider:
  - for 1.0 million people
  - plus industry
  - Includes nature reserves fro drinking water storage and production
- 1700 employees



wereld waternet

Organization founded by Waternet for international projects

Internet site: http://www.wereldwaternet.nl

(only in Dutch….)

waternet

produces the source for sewage

- That drinking water:
  - is used to transport wastes
  - is mixed with rain and groundwater
- This mixture:
  - is called waste water
  - is a problem and costs a lot of money

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Conclusion of this presentation

- Get the water out of the waste
- Use this in a clever way

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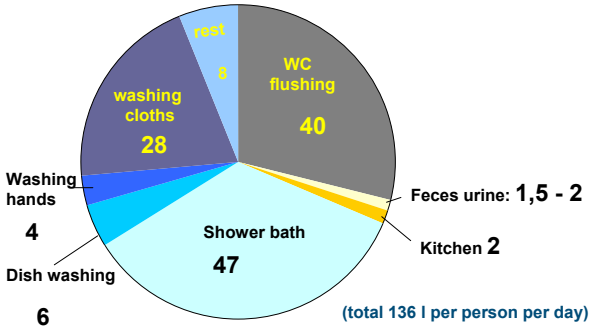
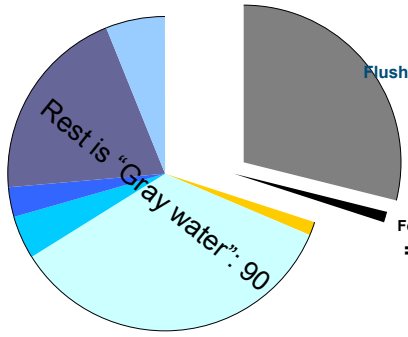
Netherlands: how many liter water per person per day?



How much??

(liter water per day?)



Bron: Adriaan Mels, WUR/LeAf

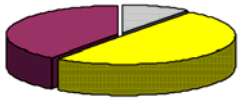
COD, N and P in separate flows

- Gray water
- Urine
- Faeces

→ Black

COD

N



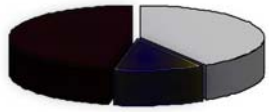
P

faeces 100 % of pathogens

Source: Adriaan Mels, LeAf

COD, N en P

- Black
- Gray water



COD

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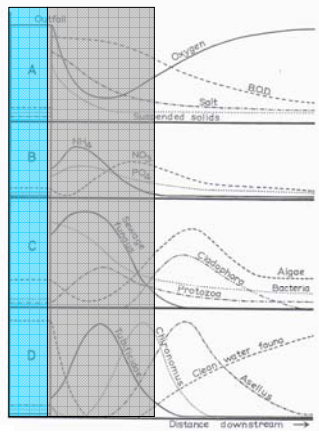
Influence of a wastewater discharge

A physical – chemical

B nutrients

C micro-organisms

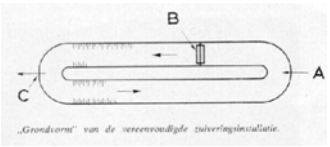
D macro-organisms



Based on Hynes, 1960 The biology of polluted waters

Oxidation ditch

developed in the Netherlands, A. Pasveer 1909 - 2001



basic idea:

just a normal ditch with an aerator, no sludge retention

only later:

the "race track" shape with activated sludge

- simple
- but still modern
- good effluent

0.05 kg BOD per kg d.s. per day

1 kg dry sludge/p.e and 250 - 300 l/ p.e. volume

Typical effluent quality oxidation ditch STP

- BOD: 2 - 3 mg/l
- NH_4: 0.1 - 1 mg/l
- NO_3: 3 mg/l

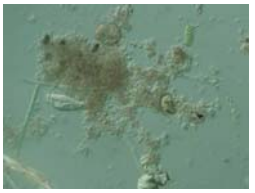
- Suspended solids: low

Better than many surface waters !!!

But faecal coli: 400 - 800 per ml !

But: Treated wastewater

- regional STP's: water from a large area
- influence at effluent discharge:
  - sludge particles, flocs
  - loose bacteria
  - odor, foam
  - low O_2



"Dead water", not satisfied with quality

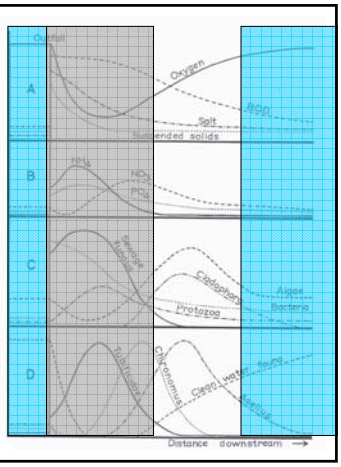
Schematic effect of discharges of wastewater

A physical – chemical

B nutrients

C micro-organisms

D macro-organisms



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The Waterharmonica:

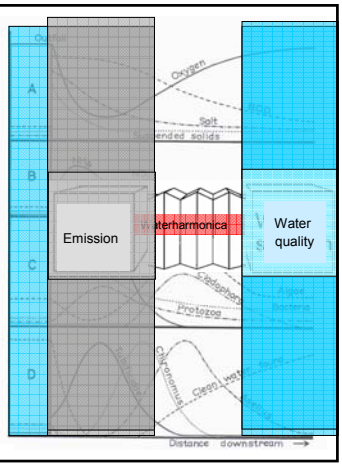
between
sewage treatment
and
surface water

A physical – chemical

B nutrients

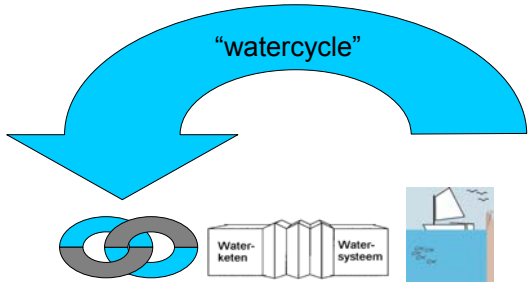
C micro-organisms

D macro-organisms



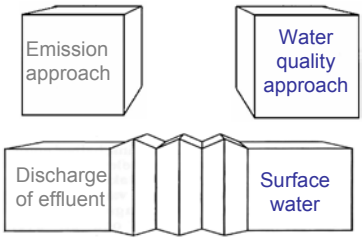
Gebaseerd op Hynes, 1960 The biology of polluted waters

Missing link in Water Management

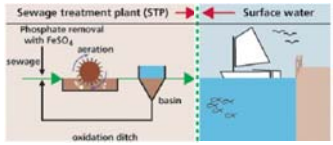


The natural link between drinking water and surface water: The Waterharmonica:

Waterharmonica as linkage-system

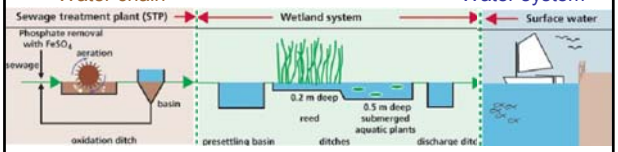


accordion, concertina, harmonic corridor



Planning of a waste water treatment

Water chain — Water system



The Waterharmonica:

the natural link between treated waste water and surface water

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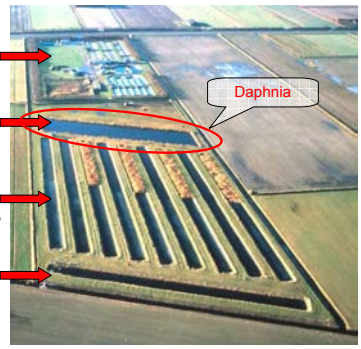
Aerial view STP Everstekoog

sewage treatment plant

presettling basin

9 parallel ditches with reed/cattail and aquatic plants

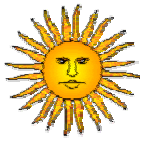
discharge ditch



Research project
1995 - 1999

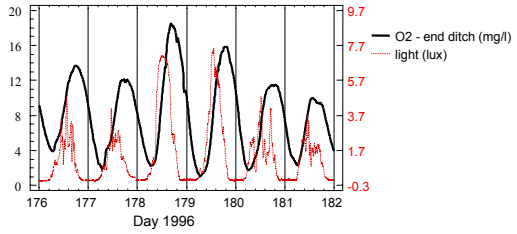
Constructed wetland

- a constructed, optimised water system
  - helophytes: reed, cattail
  - (submerged) water plants
  - plants on the banks
  - sediments
  - algae, Daphnia, etc
- works on solar energy

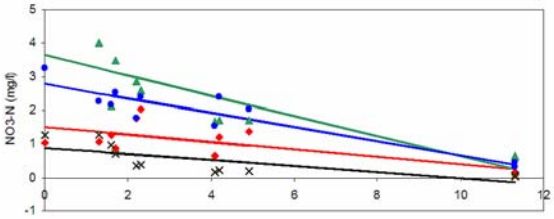


A constructed wetland to make a “living water” from treated waste water

Diurnal oxygen pattern



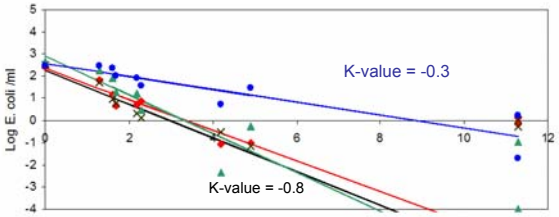
Nitrate (mg/l) vs retention time



Hydraulic retention time (days)

Spring Summer Autumn Winter

Log E.Coli (per ml) vs retention time

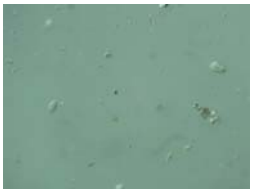


Hydraulic retention time (days)

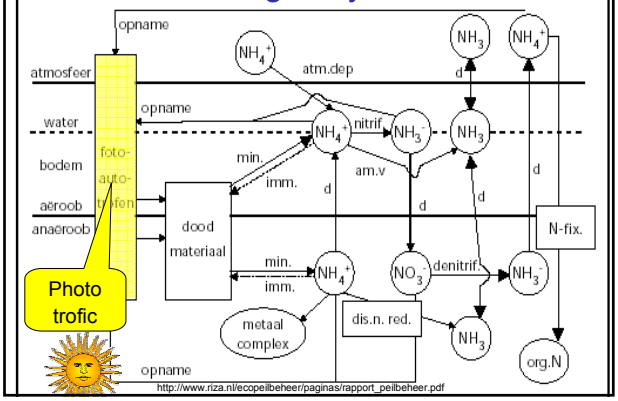
Spring Summer Autumn Winter

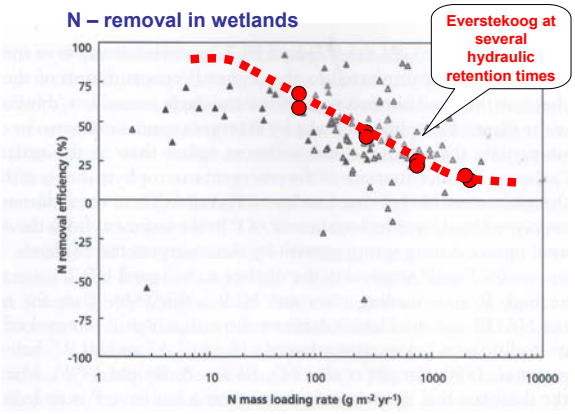
After constructed wetland different water

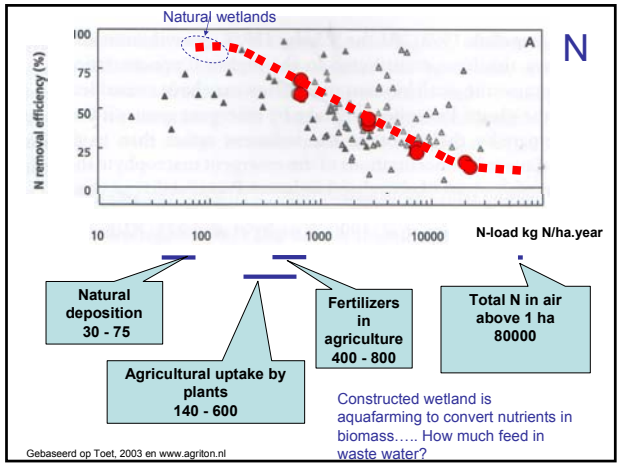
- Natural oxygen regime
- No odour
- Less sludge particles lead to desinfection
- More, but different suspended solids
- Living water:
  - algae, daphnia
  - all kind of “waterlife”
  - fish
  - birds



Nitrogen cycle



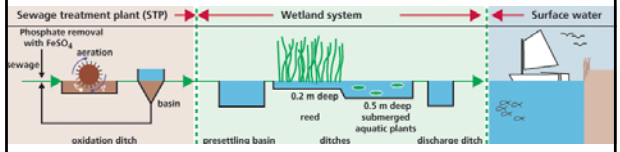




Waste or used water ??

- Waste water treatment =
  - Clever use of treated water
  - Clever use of nutrients

From wastewater to surface water



STP Oxidation Ditch

Constructed wetland

Surface water

A constructed wetland to make a “living water” from treated waste water

Aqualân Grou

urbanwatercycle

http://www.interregnorthsea.org/project-details.asp?id=1-16-31-7-37-04

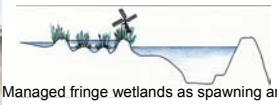
Aqualân Grou

Aqualân Grou and STP

Aqualân Grou

Grou: Combination of treatment wetland and fish spawning

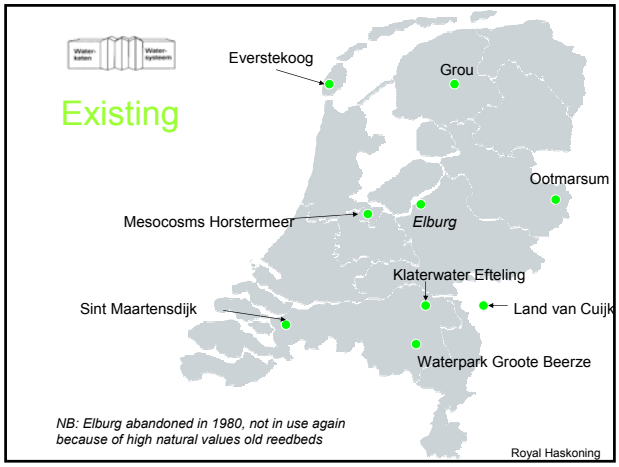
Bream-Pike perch



Managed fringe wetlands as spawning area

Pike

Pike-Roach



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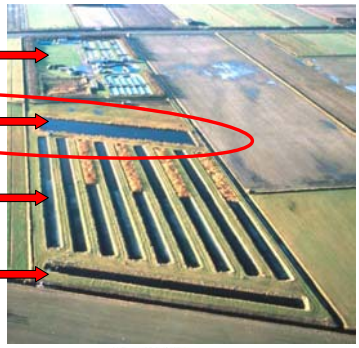
STP Everstekoog



sewage treatment plant

presettling basin

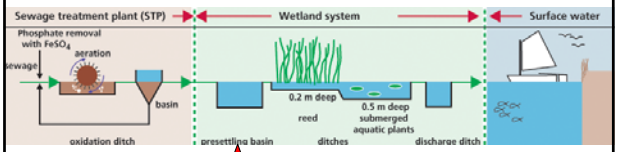
9 ditches with reed/cattail and aquatic plants

discharge ditch

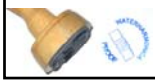
Research project 1995 - 1999

www.waterharmonica.nl

Biological filtration by Daphnia



Focus on ponds fed by well treated effluent from activated sludge plants



www.waterharmonica.nl

Empuriabrava

Daphnia

www.waterharmonica.nl

Daphnia food chains

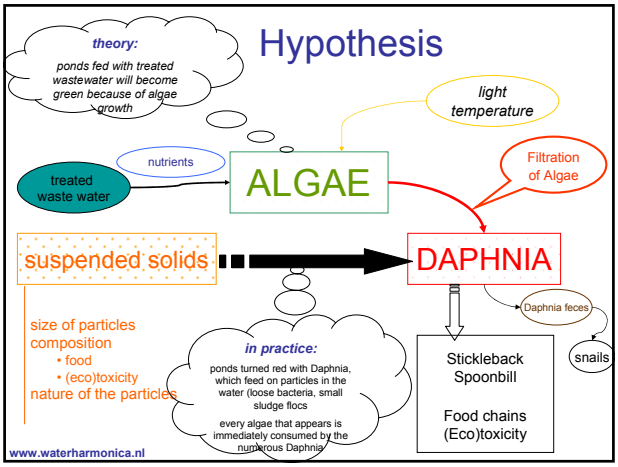
Grou

Empuriabrava

Everstekoog

www.waterharmonica.nl

Hypothesis



www.waterharmonica.nl

Horstermeer

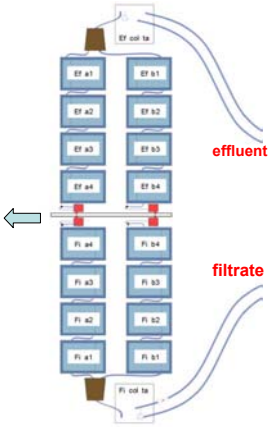
experiments in effluent upgrading

2005 – 2008

Biological filtration

Technical filtration

www.waterharmonica.nl



Research on m³ scale

4 x 4 mesocosms:
- 2 x 4: effluent
- 2 x 4: filtrated effluent

www.waterharmonica.nl

Equal experiments on three STP's

Horstermeer
Netherlands

Effluent
Filtrated effluent

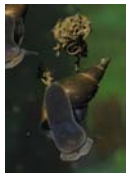
Grou
Netherlands

Parallel to ponds

Empuriabrava
Spain

Parallel to ponds

www.waterharmonica.nl



Not only Daphnia:

Suspended material and bentic algae:

- biological filtration by Daphnia
  - mainly Daphnia magna, but also other Cladacera

Attached algae and settled sludge:

- grazing by snails
  - Holland: mainly Great pond snail *Lymnaea stagnalis*

Mesocosms Horstermeer, autumn 2007

www.waterharmonica.nl

SC18 www.waterharmonica.nl SC19

Water Frame Work Directive

What is in the water?: *chemistry*

What lives in the water?: *ecology*

Aqualân Grou: fish 9 Juli 2008

	Daphnia pond	Constructed wetland	Fish spawning pond
Baars			9
Blankvoorn			54
Kleine modderkruiper			4
Paling			2
Ruisvoorn			6
Tiendoornige stekelbaars	0	23	1
Zeelt			5
Brasem			2
Driedoornige stekelbaars			1
Snoek - Pike			3
Giebel			2
Kolblei			2
Riviergrondel			6

Water quality aspects

Waterharmonica systems

- Effluent quality as good as reasonable:
  - Producing products:
    - Usable water
    - Products grown on the waste water
- Important:
  - Toxic effects and through poisoning
  - But: in practice not (yet?) many effects
  - But: caution is needed

6th IWA Conference on Wastewater Reclamation and Reuse for Sustainability
Antwerp, Belgium, 9-12 October 2007

Mainly focus on "end of pipe" methods, but also:

- "Treat and discharge is becoming "old-fashioned"……
- Develope strategies with less "environmental impact"
  - Lack of water leads to water reuse
  - Desalination: energy consumption
- Water reuse is multiple use of water

Slide kindly provided by Lluis Sala, Consorci de la Costa Brava, IWA, 2007, Antwerp

- Already after adequate biological secondary treatment useful
  - –But "upgrading" is needed

Get the water out the waste"

Why reuse in dry regions?

- Greater overall water demands per capita -agricultural irrigation
- Increase in population, tourism
  Paaivijver
- Irregular rainfall patterns and exposure to frequent droughts
- Future need to comply with the WFD, a challenging task

Source: Knight, C.G. and Staneva, M.P., 1996, Water Resources Bulgaria

This presentation

- Waternet: the first watercycle company in the Netherlands
- *Conclusions of this presentation*

Part 1:

- Waste water: get the water out of the waste?
- Effect of a discharge: biology of polluted surface water
- Waterharmonica: The Waterharmonica: the natural link between treated waste water and surface water
- Waterharmonica: practical aspects
- Biological filtration natural values → European Water Framework Directive
- **European examples**

Part 2:

- Nepal, Tanzania, Kenya
  - Polluter pays???
  - No money for waste water treatment?

Conclusions

Saxion University, Wednesday 7 January 2009

Successful water reuse projects in southern Europe: France

Lagoons for upgrading treated waste water for agricultural irrigation

- Noirmoutier:
  - Tertiary treatment by lagooning for 6,100 m3/day.
  - Irrigation of 500 ha of high value crops (potatoes) and protection of shellfish areas. Demand of farmers for the reuse of 100% of wastewater.
- Clermont-Ferrand:
  - Tertiary treatment by lagooning for 10,000 m3/day.
  - Irrigation of 700 ha of corn.
  - First EU epidemiological study: no adverse health effects

Photos by courtesy of Dr. Valentina Lazarova

Slide kindly provided by Lluis Sala, Consorci de la Costa Brava, IWA, 2007, Antwerp

Successful water reuse projects in southern Europe: Empuriabrava, Spain

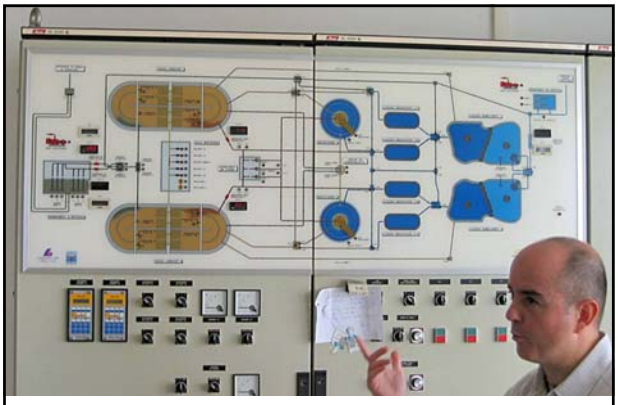
Wetlands for upgrading treated waste water for agricultural irrigation

- Environmental reuse (funded with EU Cohesion Funds)
  - Empuriabrava, Costa Brava, Spain: Since 1998, approx. 650,000 m3/year
  - Effluent is further polished in a 7 ha constructed wetland.
- Reclaimed water is used at the Aiguamolls de l'Empordà Natural Park
  - to recreate wetlands and restore vanishing wet meadows,
  - Improving an ecosystem of high value and that has suffered a steady decline in quality

Photos by courtesy of Consorci de la Costa Brava

Slide kindly provided by Lluis Sala, Consorci de la Costa Brava, IWA, 2007, Antwerp

Empuriabrava constructed wetlands as a recreation of a natural wetland



Explanation by Lluis Sala

STP with the first ponds

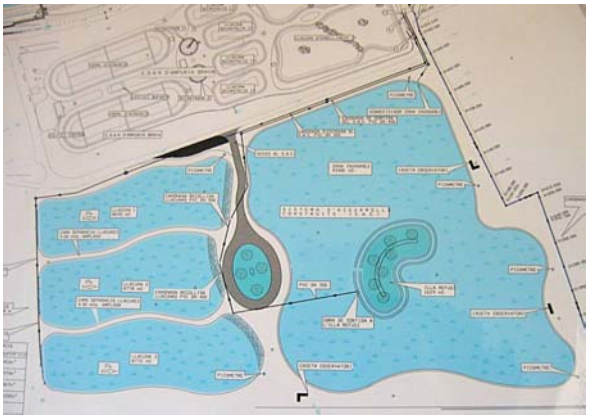
Daphnia gallore

Mesocosms Empuriabrava – rechterdeel met schaduwdoek

Part of the nature area

Hides

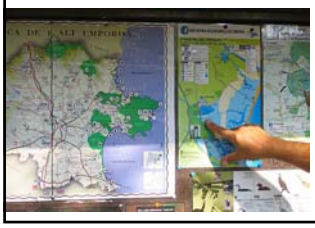
Hiking and biking



The constructed wetland

The more “natural” wetland

National park
Aiguamolls d l'Emporda



Use of enhanced waste water in nature

Wetlands to upgrade existing plants

A – to improve a bad functioning plant

B- to improve effluent quality

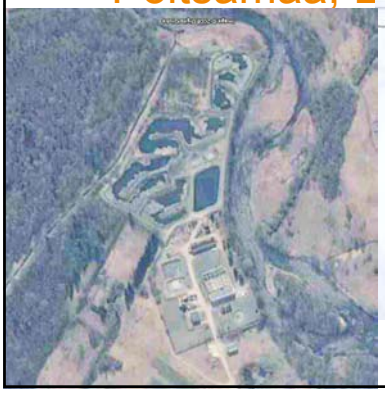
Põltsamaa, Estonia

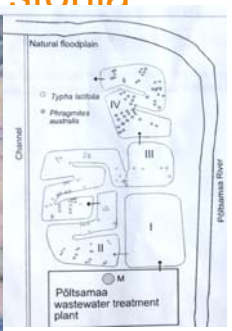
- Activated sludge plant
  - Overloaded,
  - not well functioning 5000 p.e.
- Four ponds:
  - 1.2 ha
  - 0.5 m deep
- Load: 4 cm/day
- Retention time: 10 days

First pond filled with sludge, not discharged on the small stream

Source: Mander, Tartu University, Estonia

Põltsamaa, Estonia





Removal efficiency

BOD - 70%

P - 30 %

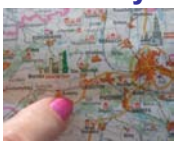
NH_4 – 40 %

Verdict:

Not impressive?, but cheap!

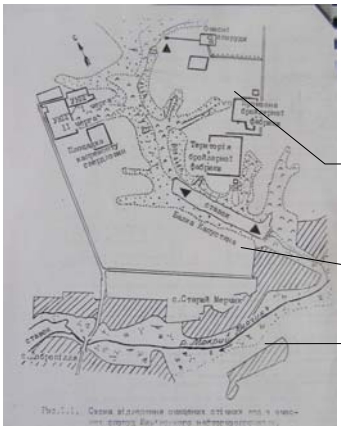
How to optimize ??

Yulievsky constructed wetland, Ukraine



- Load to the wetland 800 p.e.
- Seemed to be an economic solution to upgrade the existing plant
- Cost: 25.000 UAH instead of 400 000 UAH estimated of new STP

- www.waterharmonica.nl/cases_waterharmonica/cases_rest_europa/oekraine/julievsky/yulievsky.htm



Conclusion of the first part of this presentation

- Get the water out of the waste
- Use this in a clever way

Statement 1: The basis of waste water is drinking water

- That drinking water:
  - is used to transport wastes
  - is mixed with rain and groundwater
- This mixture:
  - is called waste water
  - is a problem and costs a lot of money
- It is a waste to waste waste water because it is "waste in water":
  - Make the quality good enough for reuse:
    - Either direct for reuse
    - Or give it back to nature and use it later

"Producing on demand"

Statement 2: No future without history

- My grandfather used his balck wastes in his garden
- He knew:
  - it was a good fertilizer
  - you had to leave the black wastes for over year
  - To use peat or saw dust to cover, etc
- But for comfort piped water……..

This presentation

- Waternet: the first watercycle company in the Netherlands
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Part 2:

- Nepal, Tanzania, Kenya
  - Polluter pays???
  - No money for waste water treatment?

Conclusions

Saxion University, Wednesday 7 January 2009

Part 2: Nepal, Tanzania, Kenya

- Discharge or reuse
- Polluter pays
  - But when no money for waste water treatment do not provide drinking water to households
- Wastes brings money
  - (re)use of treated waste water
  - integrated use of wastes

Workshop on water management in Nepal

A Workshop on community management of waste water(treatment and disposal) in low-income, semi-urban communities in the Kathmandu Valley, Nepal,

2-13 November 1998

Closing the nutrient cycle

Why and how

A way to reduce waste water problems in Nepal

More on www.rekel.nl/water

http://www.rekel.nl/water/nepal_workshop/index.htm

Solutions - basics

- Aimed on the communities, done by the communities
  - short term solutions:
    - self aid
  - long term solutions:
    - with foreign aid, but:
      - aimed on making jobs, income
      - minimalise loss of nutrients = chemical fertiliser:
        - » close the nutrient cycle
- Based on the local culture and knowledge

THE POTENTIAL OF WATERHARMONICA CONCEPT IN TANZANIA

Saxion Hogescholen

"The bridge between treated wastewater and surface water"

Presented by: Hamidar Chanzi

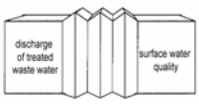
IBP 2004/5 - Environmental Science, Saxion University – Deventer

Waterboard Hollands Noorderkwartier, July 11, 2005

Main research question of Chanzi Hamidar

Waterharmonica

What is the potential of this Dutch initiative for Tanzania?



Flush and discharge

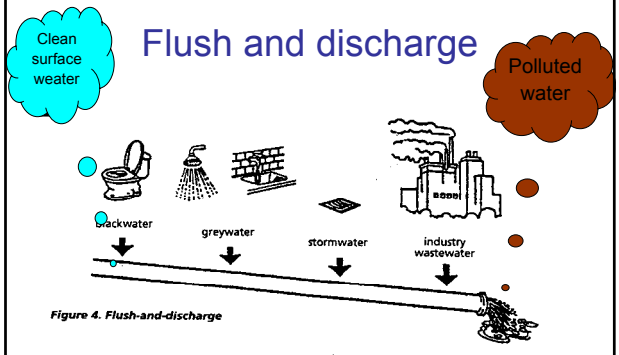


Figure 4. Flush-and-discharge

Winblad, WHO, 1996

Waste water in Tanzania

wastewater only produced by 5 % of population

- but this 5 % is the wealthiest part
  - offices,
  - hotels, hospitals

" like in most developing countries…….
and situation likely to worse"

Double Vault separation toilet

Safe fertilizer

Short term solution for 80 – 90 % of the population

Enough fertiliser for the country

A Dutch latrine

Hamidar Chanzi "from Tanzania,
in the museum "Het Kleine Huisje, Schermerhorn, 2005

This works:

- As long no drinking water delivered in the houses, because then:
  - → Water flushed toilets
  - → Waste water
  - → Surface water pollution while no money for sewage treatment

Cost of water management in The Netherlands

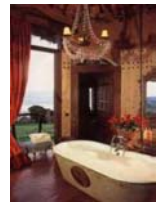
per family in Euro/year

Organisation		Cos
Waterboards	"Dry feet"	50
Communities	Sewers	100
Waterboards	Sewage treatment + surface water quality	150
Water companies	Drinking water	165
	Total Euro 450 per family per year	

Based on Dutch Ministry of Transport, Public Works and Watermanagement, 1999

Polluter pays?

The New Arusha Hotel
160 USD for double room
140 USD for single room
Dik Dik Hotel
120 USD for double room
100 USD for single room



Polluter pays

Example Masai Mara National reserve :

- **"Mara Simba** is the only lodge in Kenya which has installed a Waste Water Treatment Plant. The plant was imported from U.S.A. This plant treats all the sewage and produces crystal clear water which is then used for irrigation. We are truly the only environmentally friendly lodge in Kenya"

Why not in Tanzania?

http://www.marasimba.com/introduction.html

Minimise risks

- Treatment of wastewater
  - Good quality of treated waste water
    - Degree of pathogen and chemical removal
- Crops restriction
  - Crow crops with less risks to worker and consumers
- Proper use of crops and fish
  - Boil, not eat fresh crops (vegetable or fruits)

Conclusions

Waterharmonica concept is a promising approach that could promote the livelihood of local people in Tanzania

-Waterharmonica makes waste water safe

-reduce water pollution: better surface water quality

-Safe fertilizer of nutrients from safe wastewater

-agriculture, aquaculture

-Polluter pays make waste water a resource

-Water conservation

-wastewater for irrigation; fresh water for domestic uses

Finally: Some "wise words"

- "Waste water comes from drinking water"
- Do not talk about water reuse, it is "wise use"
- Polluters pay
- No drinking water when no money for sewers and treatment is available but separation
- When waste water: treat it well and use it
- Surface and (ground) water quality is important
- Think global(ly) and in water cycles

The Waterharmonica: natural link between tap and source !

Improving agricultural practices as a way to meet the Millennium Developments Goals:

a demonstration project in the Shimo la Tewa prison in Mombasa, Kenya

Ruud Kampf
Waternet / Vrije Universiteit Amsterdam

Adriaan Mels, Nelson Opoku and Frederick Tettey-Lowor
Wageningen University and Research Centre and LeAF

This presentation

- A wetland-lagoon system for wastewater management at Shimo La Tewa Prison, Mombasa – Kenya
- One step further:
  - integration of agriculture and sanitation in the Boys prison to support a novel but old-fashioned Ecosan approach

Shimo la Tewa Prison
Mombasa, Kenya

a constructed wetland lagoon system for improving the sanitary situation

UNEP-GEF WIO-LaB PROJECT

ADDRESSING LAND BASED ACTIVITIES IN THE WESTERN INDIAN OCEAN

Coastal Development Authority, Mombasa
Mombasa Water & Sewerage Company
Kenya Marine and Fisheries Research Institute
Dar es Salaam University, Tanzania

a "do something project"
with very well defined goals

Some headlines of the Project

1. coupled wetland-lagoon STP
2. education and awareness
3. learn to manage the system
4. reuse in agriculture and aquaculture
5. reduce pollution

The prison

- Inmates:
  - Main prison for man: ca. 2.200 pers.
  - Woman prison: ca. 300 pers.
- Shima Annex Prison
  - Farming,gardening activities: 300 pers.
- Boys prison: 300 pers.
- Staff quarter
  - About 1500 staff and family
  - Close to the prisons, but scattered over the area
- Total surface ca. 250 ha

Inside a cell

Toilet facilities

Discharge through a separate sewer system: very concentrated waste water, seperate urinals

Outside room for day use

The open gutters were originally designed for rain discharge (monsoon climate!)

Now also “Grey water”

Education, training

are important part of prison life

One of the inmates, will be a good tailor when he comes out

Payment every year at Christmas

The metal workshop

Paint workshop

NAIROBI CONVENTION

WIO-LAB in Kenya

Addressing Land-based Activities in the Western Indian Ocean

OFFICIAL LAUNCH OF THE SHIMO LA TEWA WASTE WATER MANAGEMENT PROJECT, MOMBASA ON 29TH AUGUST, 2008

- Improving sanitary situation in the main prison
- Improvement and construction of:
  - Sewage system
  - Large septic tank
  - Subsurface constructed wetland
  - Fishpond

Ready end of October 2008

Project Coordinator
Dr. Nesbert Mangale
Managing Director
Coast Development Authority (CDA)
Mombassa, Kenya
Tel: +254 41 2224490/06
E-mail: cda@cdakenya.org; md@cdakenya.org

Could we make one step further?

The chosen solution:

– is only for a part of prison

– does not fully use reuse potential

Exploration of the way to go:

– source separation and reuse of wastes

– use Ecosan / Ecological Engineering principles

– integration of agriculture and sanitation

Overview Shimo la Tewa prison
- 250 ha
- Agriculture: undeveloped but important

Key ideas

– What is the difference between animal manure and "human manure"?

– Solutions should be based on local agricultural practices

– How much is this influenced by cultural and health aspects?:

- A prison is different from the "outside world"

A project in Shimo la Tewa
Boys prison or Borstal institute

- *300 boys*
- A special and attractive platform for a demonstration project on a small scale
- *Knowledge can be replicated in other Kenyan prisons and abroad*

Education even more important then in the Main prison

Agriculture in prison

Plant nursery

- Mrs Lina E. Bonto

Dr. Rene D. Haller
Baobab Trust

Learn how to sustain a family on 1000 m^2

Nguuni Environmental Education Centre

Farmer Field School Training Programmes

Learn how to grow fish on the home farm

Kenyan Prisons Service Mission Statement

Baobab Trust

dr. Haller

a good neighbouring partner in:

- logistics of black wastes
- seeking solutions in production of biogas and manure
- education of inmates in farming, aquaculture: how to set up an honest business in rural areas

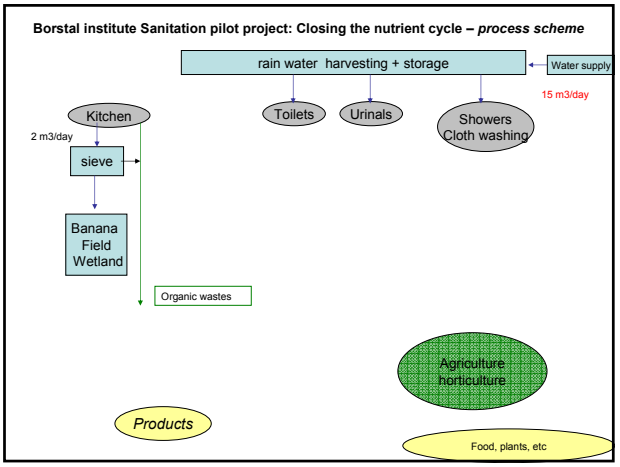
For more information on Baobab Trust and dr. Haller:

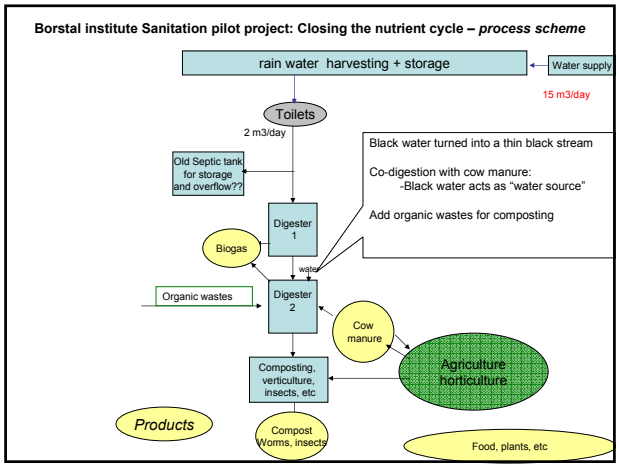
www.thebaobabtrust.com/

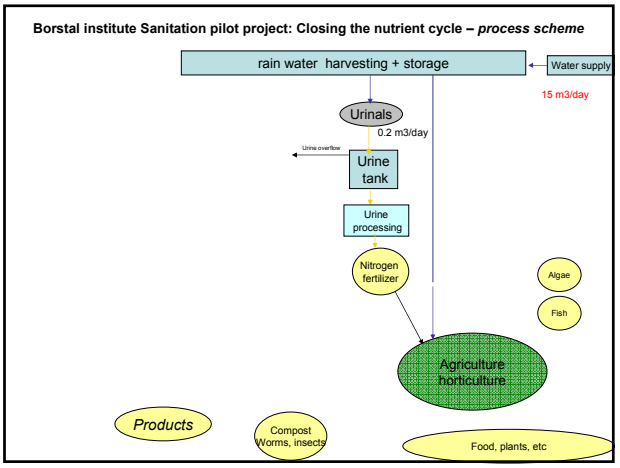
www.iees.ch/EcoEng032/EcoEng032_IntHaller.html
http://www.thehallerfoundation.com/
http://www.bamburicement.com/rehab.htm

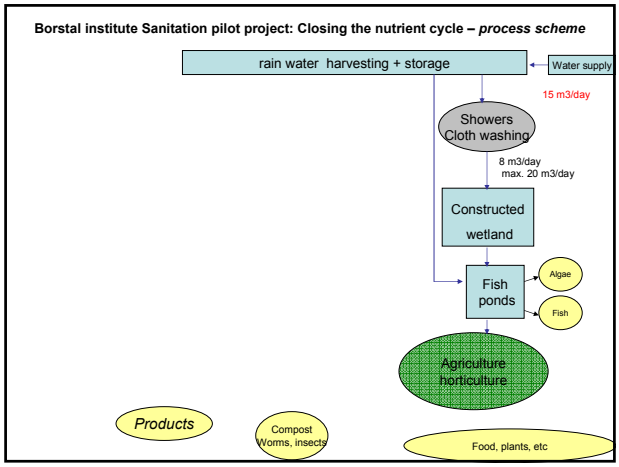
Ghanese Students Wageningen University

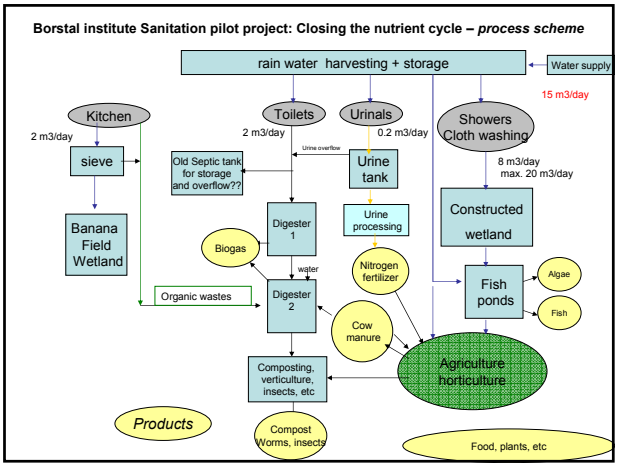
- Frederick Tettey-Lowor
  - Exploration of civil aspects, making pre-design
- Nelson Opoku
  - Overview of agriculture in prison
  - Possibilities of the integration of agriculture and sanitation











Quantities

- Rainwater harvesting
  2 tanks of 50 m3. Why no bigger underground storage?
  - One third of water need
- Sanitation
  - 4 Ecosan toilets, amount black wastes:
    - 1700 l/d (design 2000 l)
  - ? Urinals, 50 % of urine separated
    - 200 l/d (design max 400 l/d)
- Grey water
  - Shower plus cloth washing 42 l/person.day = 42 m3/day
- Kitchen
  - 6 l per person per day: 2 m3/day

Status of the Borstal institute project

- Project set-up has been approved
- There is money:
  - € 59.162 funded by Aquaforall
  - plus expert cost, etc.
- A good local team
  - Coastal Development Authority
  - Kenyan prison systems
  - Mombasa Water & Sewerage Company
  - Ministry of Agriculture
  - Baobab Trust
  - Local companies Green Water, JuaNguvu Ltd
- Through several reasons:
  - Project start slow
    - Project management
    - Phasing of the project
- But:

Mrs Kireri,

Officer in charge of the Shimo la Tewa prison

Mrs Solomon,

Officer in charge of the Borstal Institute

Mrs Bendera,

Project leader CDA

Teachers, officers of the boys prison staff of CDA

Photo: Nelson Opoku

Local workshop

Visit to the Baobab demonstration farm

Boys selected to be involved in the project

Photos: Nelson Opoku

Borstal Institution
Boys prison of Shimo la Tewa

www.waterharmonica.nl

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Conclusions

Saxion University, Wednesday 7 January 2009

Conclusion of this presentation

- Get the water out of the waste
- Use this in a clever way

Sewer systems

- Already available on a big scale
- Relatively cheap
- Long life span

- But……...

Is a sewer system clever ??!!

Per inhabitant per year:

50 l faeces, 500 l urine plus 100 l kitchen wastes

+ 15.000 l drinking water, mainly for “transport”

+ 15.000 l rain

➔ large and expensive sewers

But as we will learn:
every **disadvantage** has his own **advantage**

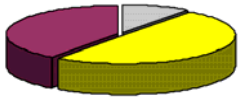
COD, N and P in separate flows

- Grey water
- Urine
- Faeces

→ Black

COD

N



P

faeces 100 % of pathogens

Source: Adriaan Mels, LeAf

Separation of water flows

- **White** - rain
- **Black** - faeces and urine
- **Grey** - washing and rinsing, kitchen
- **Mixed** - do not mix??

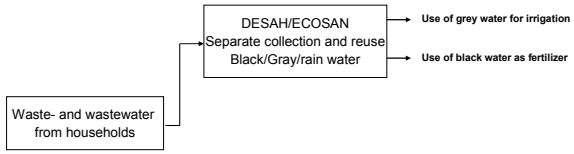
Conventional wastewater treatment

Sewage from households → Combined collection •sewerage systems •sewage treatment → Discharge of treated wastewater into receiving water bodies

Characteristics

- Expensive in construction
+ *Relatively cheap in exploitation*
+ *Large scale experiences*
+ *Proven approach*
+ *Useable for rainwater discharge in urban areas*
- Sustainability: leakage, storm water discharge

Source separation?

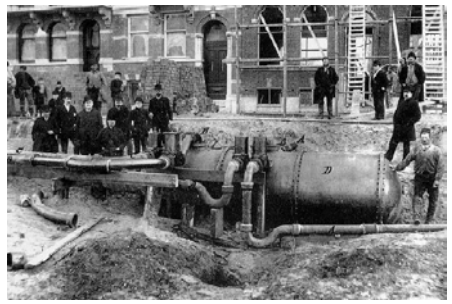


Based on Mels, 2004

Separate drainage is not new

The Boldoot car: Honey buckets in Amsterdam

The vacuum sewage system of Charles T. Liernur (1828 - 1893)

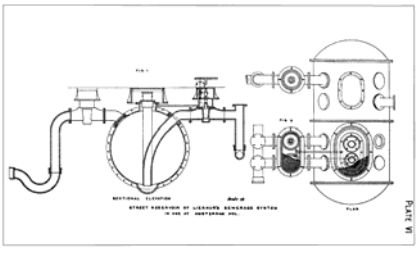


With thanks to Adriaan Mels (LeAF, Wageningen UR), based on Thesis Van Zon, 1986

Liernur collection of black wastes for reuse in agriculture

- Underground iron sewer
- Vacuum transport of faeces and urine

•iron toilets



Steam mobile with air pump used by Liernur

http://www.bronnenuitamsterdam.nl/weergave.asp?ID=16

Around 1900

Practical use of Liernur system in:

- Leiden 1200 people; 1870-1915
- Dordrecht 800 people; 1872-1887
- Amsterdam 1700 people; 1872-1912

- St. Petersburg 22.000 people
- Prague 10.000 soldiers

Liernur: profitable production !!

- manure or “poudrette”
- ammonium sulphate

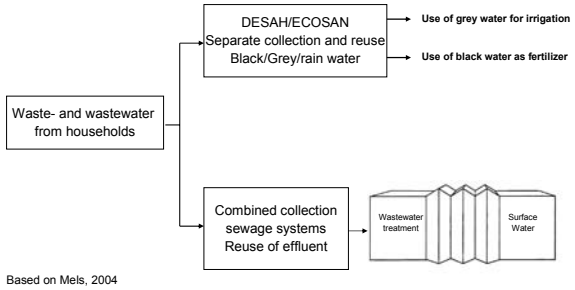
In Amsterdam profitable from 1897 - 1915 !!

Disappeared:
- Ahead of time?
- Introduction of water closets

- Source separation is very attractive
  - Not only ancient examples, but really applicable
  - But:
    - up to now only on small scale
    - expensive when sewer system already exists
    - But very, very attractive in the developing world

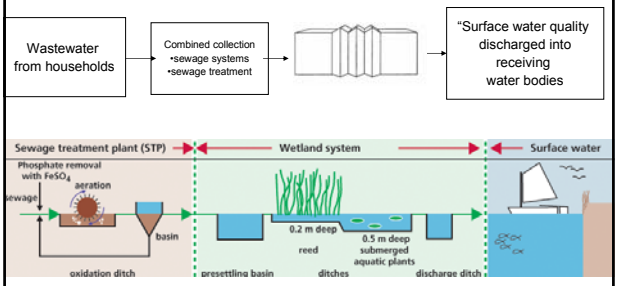
www.waterharmonica.nl

Waterharmonica as alternative for source separation

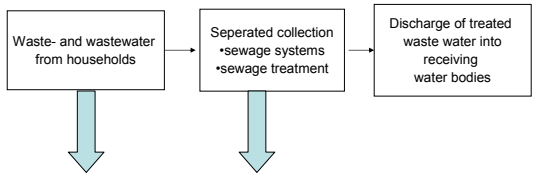


Based on Mels, 2004

Waterharmonica



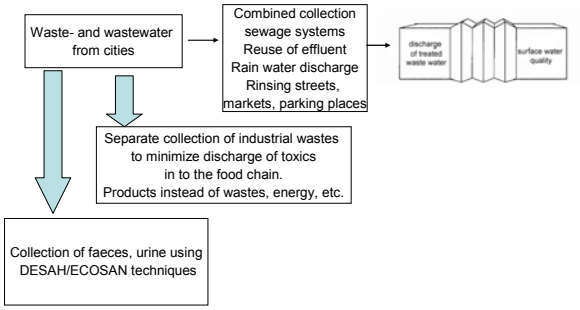
Rain water policy in the Netherlands



NO Rain Water In Sewers
Less sewage,
Lesser rain water outlets
-ETC
-ETC

•NORIS:

Waterharmonica plus separate sanitation plus clever sewage management



Conclusion of this presentation

- Get the water out of the waste
- Use this in a clever way

Sources

- www.waternet.nl
- www.waterharmonica.nl/
- www.rekel.nl/water

Presentations provided by Lluis Sala:

- www.ccbgi.org
- www.ccbgi.org/docs/antwerp_2007/eu-med_initiative_sala_et_al.pdf
- www.ccbgi.org/docs/antwerp_2007/constructed_wetlands_014.pdf