Life Cycle Assessment
A Decision - Making Tool,
Wastewater Treatment Facilities

INNOVA – MED
Innovative Processes and Practices for Wastewater
Treatment and Re –Use
Ankara, October, 8 – 11, 2007

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Ph.D, DIC Suez Canal University
Egypt

This presentation, An Overview

- The main objective of this presentation is to introduce Life Cycle Assessment LCA as one of the viable environmental management tools.
- To highlight the role of LCA in decision making processes relevant to wastewater treatment plants.

Presentation Contents

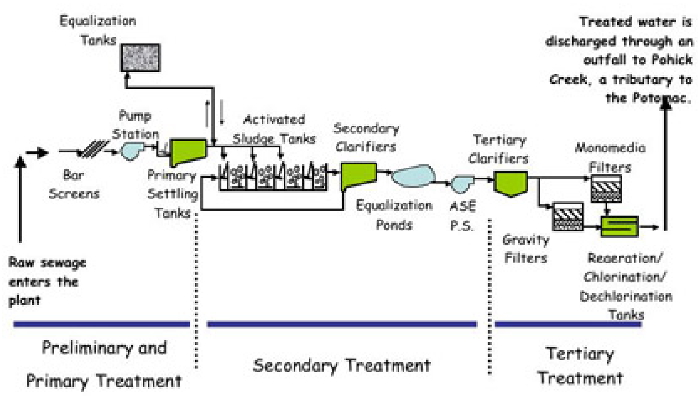
- Environmental Management Tools in Water Industry
- Life cycle assessment, an introduction
- Life cycle assessment as a decision making tool in WWT facilities

Wastewater Reuse, is Becoming a Must

- In view of the current situation of limited water resources, the need of wastewater reuse is becoming a strategic need
- Sharp increase in WWTP is reported everywhere*…
- WWTP, different technology, different construction, varied cost, different impacts
- The need for a good decision making tool

Wastewater treatment facility is a complicated structure
Different processes, different techniques, with lot of risks involved

Wastewater Treatment Process



WWTP, Some Excerpts,1

Energy Use at Wastewater Treatment Plants

- **Wastewater treatment is the single biggest electricity use for most local governments.**
- **At the plant, energy makes up 25-40% of total operating costs, second only to labor.**

Source: EPA

WWTP Some Excerpts, 2

Energy Use at Water and Wastewater Facilities

- Water and wastewater pumping and treatment use about 4% of all electricity consumed in the U.S. ($^4/_5$ for pumping, $^1/_5$ for treatment)
- The EPA estimates that water and wastewater treatment plants will need to increase their capacity by 5-8% over the coming decade to keep up with demand.

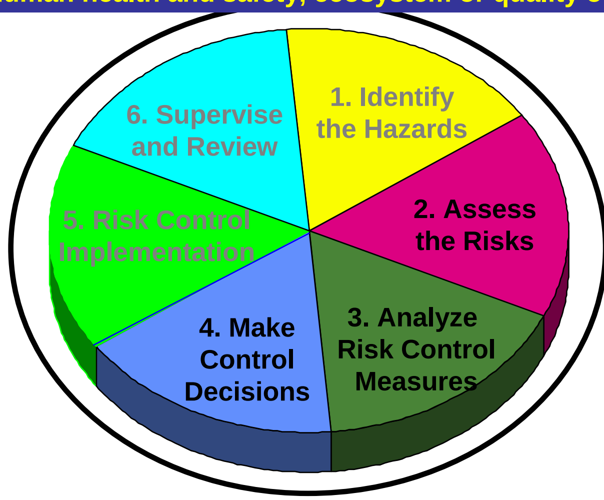
How to Manage Risks

Wastewater Environmental Management Tools

A quick appraisal

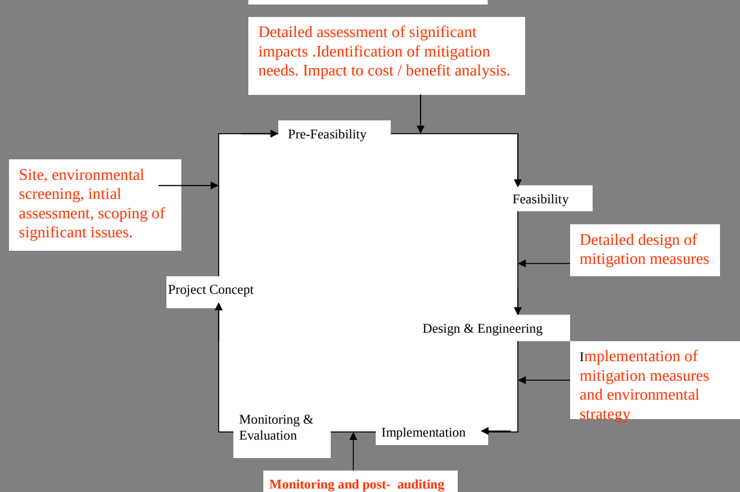
- Risk Assessment, human and environment
- Environmental Impact Assessment
- Life Cycle Assessment

Risk Assessment is a tool to measure the probability of an adverse impact on either human health and safety, ecosystem or quality of life



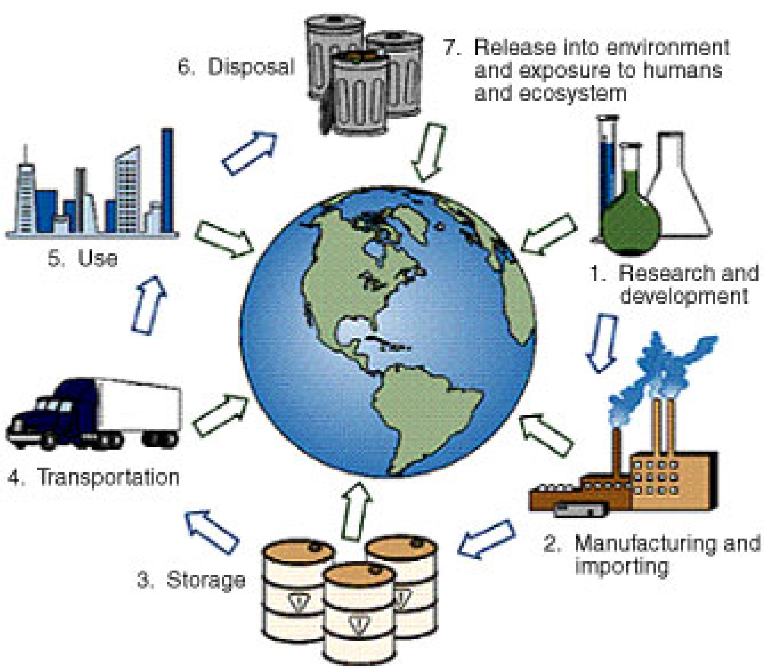
Zero Risk Does Not Practically Exist!

EIA and the project cycle



Importance of LCA

- Better decision-making for product/production and services systems based on sound comparison between different alternatives
- Identifies key impacts and life-cycle stages of system
- Provides a basis for environmental improvements of system
- Identifies trade offs
- Identifies information gaps and where we can improve the system



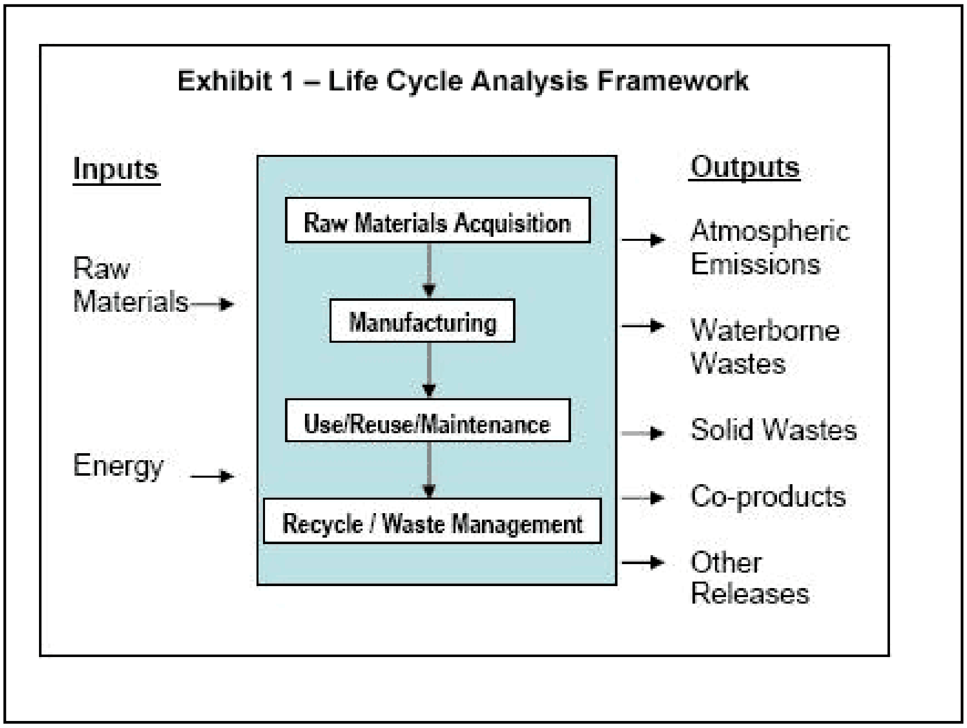
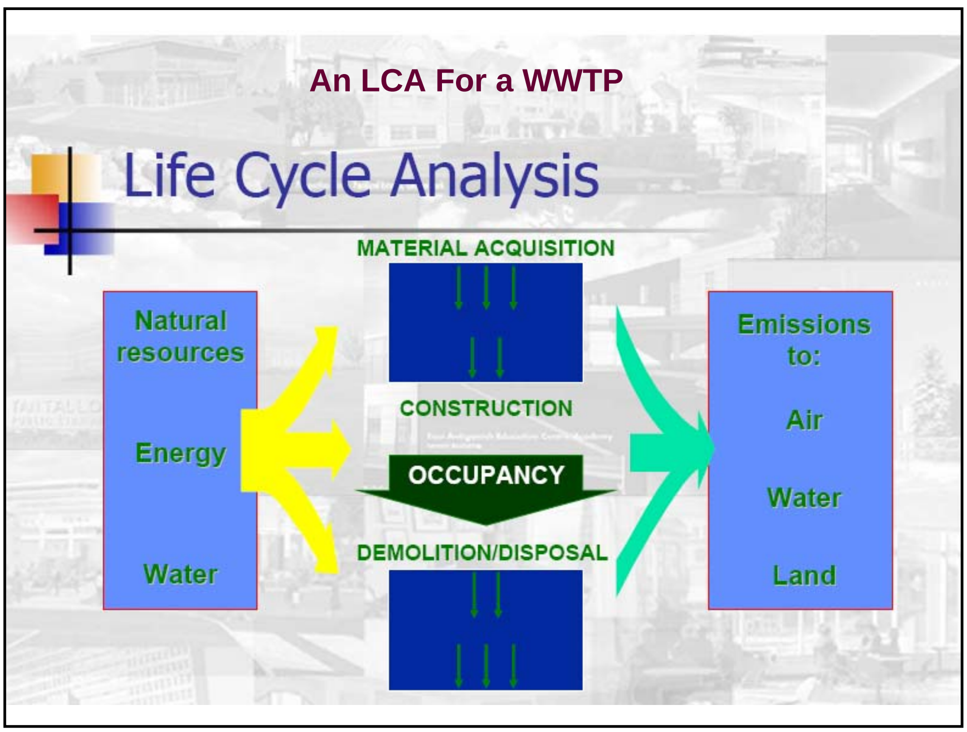


Exhibit 1 – Life Cycle Analysis Framework
Inputs
Raw Materials
Energy
Raw Materials Acquisition
Manufacturing
Use/Reuse/Maintenance
Recycle / Waste Management
Outputs
Atmospheric Emissions
Waterborne Wastes
Solid Wastes
Co-products
Other Releases


An LCA For a WWTP
Life Cycle Analysis
MATERIAL ACQUISITION
CONSTRUCTION
OCCUPANCY
DEMOLITION/DISPOSAL
Natural resources
Energy
Water
Emissions to:
Air
Water
Land

Life Cycle Assessment in WWTPs
Some Case Studies

Sustainability of Wastewater Treatment Systems

"A Sustainable wastewater system should, over a long time perspective provide required services while protecting human health and the environment, with a minimum use of scarce resources."

- *Most publications base the assessment/comparison on the operation of the treatment systems, not on the full life cycle.*
- By wastewater treatment we may contribute to solving one problem (the receiving environment) but the technology chosen may contribute to the creation of other problems (e.g. by being very energy consuming)
- Sustainability concept challenges us to look at wastewater treatment systems from a life cycle perspective and to introduce long term thinking (changes of the wastewater concept from end of pipe treatment towards resource utilization)

Life Cycle Assessment of waste water treatment systems

Environmental impact comparison of Activated sludge treatment and Membrane Bioreactor treatment

LCA OF DRINKING AND WASTEWATER TREATMENT SYSTEMS OF BOLOGNA CITY: FINAL RESULTS.

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MUNICIPAL APPLICATIONS OF LCA II

Applying Life Cycle tools and Process Engineering to determine the most adequate treatment process conditions. A tool in environmental policy.

Prof. Omar Romero
Instituto Tecnológico Autónomo de México, Industrial Engineering Department
oromero@itam.mx;

Life Cycle Considerations for selection of Wastewater Treatment Alternatives

S. V. Srinivasan, E. Ravindranath and S. Rajamani,
Department of Environmental Technology, Central Leather Research Institute, Adyar, Chennai – 600 020, India
srinivasansv@yahoo.com

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Life cycle assessment of wastewater treatment technologies treating petroleum process waters

N. Vlasopoulos [a,*], F.A. Memon [c], D. Butler [c], R. Murphy [b]
[a] Department of Civil and Environmental Engineering, Imperial College, London SW7 2AZ, England, UK
[b] Department of Biological Sciences, Imperial College, London SW7 2AZ, England, UK
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Life Cycle Assessment, a Decision-Making Tool in Wastewater Treatment Facilities

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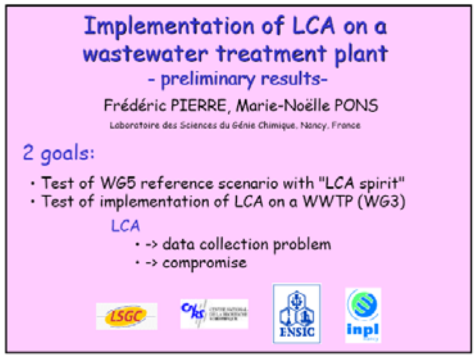
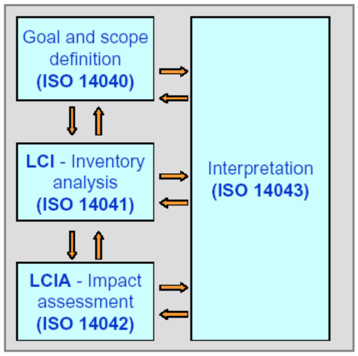


LCA, The Process

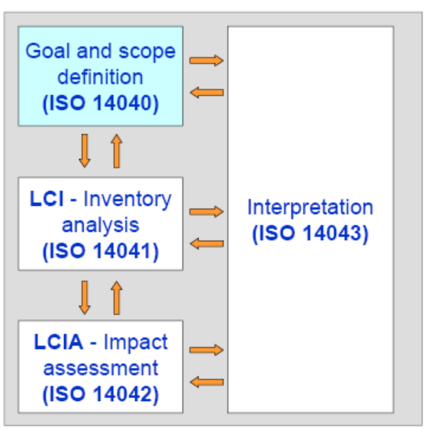
LCA Components

ISO 14040 – 4 Phases of LCA



FIRST ENVIRONMENT

Goal and Scope Definition



Specifying:

- Reason for conducting the study
- Intended use of study results
- Intended audience
- System boundaries
- Data requirements
- Study limitations

FIRST ENVIRONMENT

Life cycle assessment of wastewater treatment technologies treating petroleum process waters

N. Vlasopoulos [a,*], F.A. Memon [c], D. Butler [c], R. Murphy [b]

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2.2.1. Goal and scope

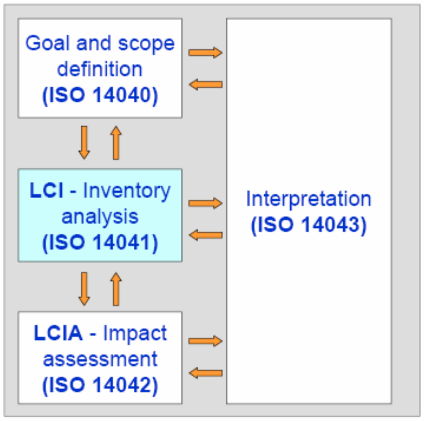
The primary goal of the research was to evaluate the environmental impact of the treatment technologies and their combinations that are capable of producing water quality required for the end uses in Table 3. It was assumed that the facilities needed for each technology are a conventional factory where the process water treatment is the "product" and the resources, energy use and possible wastes are the inputs and outputs coming in or out respectively from this factory in order to produce the desired "product".

Goal and Definition
The study aimed to ascertain which treatment and Treatment combinations are good enough to meet The following end use

Table 3
Typical quality requirements for nine different end uses

	Agricultural use							Industrial use	
	Barley	Alfalfa	Wheat	Sorghum	Cotton	Rhodes	Citrus	Cooling system feed	Boiler feed
Boron (mg/l)	1	6	0.65	5	6	6	0.5	10	10
Sodium (mg/l)	200	250	200	250	500	500	150	2500	1000
TDS (mg/l)	5000	2500	5000	3000	7000	6000	1200	5500	2200
Oil (mg/l)	1	1	1	1	1	1	1	1	1

Life Cycle Inventory



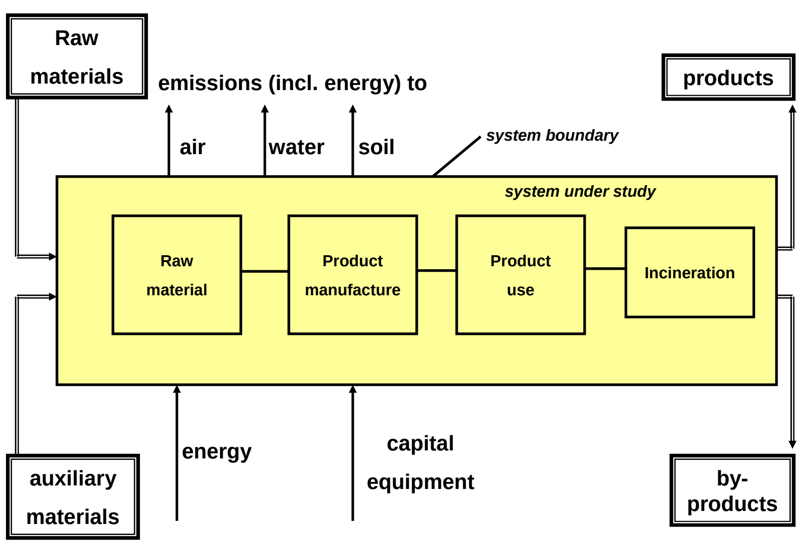
Collecting data and quantifying:

- Material use
- Energy use
- Environmental discharges to air, water, land,
- Waste

Associated with each life cycle stage

FIRST ENVIRONMENT

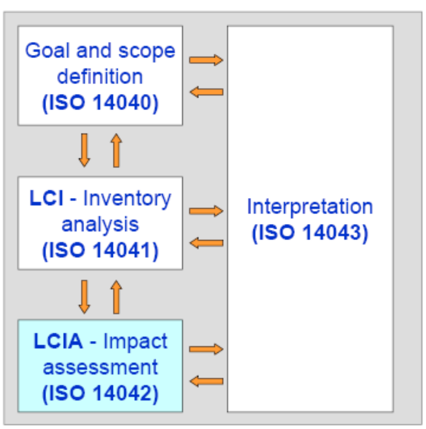
An inventory analysis



Example of an inventory table Comparing the LCI of Two WWTP *(hypothetical)*

intervention (kg)	WWTP A	WWTP B
resources		
crude oil	37000	22000
natural gas (m3)	400000	0
emissions to air		
Cd	2.9	0
Cu	0	850
NOx	2000	150
SO2	1000	80
CO2	800000	50000
CxHy	30	40
NH3	230	0
emissions to water		
Cd	3	0
Cu	2	20
Ni	0	15
P	3500	1000
NO3-	180000	260000
emissions to soil		
Cd	4.5	1
Cu	0	850
Zn	0	1400
P	0	40000

Life Cycle Impact Assessment



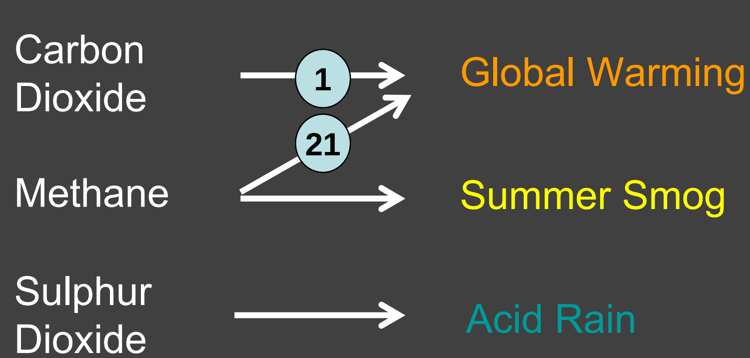
Translating the inventory into potential impact on human health and the environment

FIRST ENVIRONMENT

Impact assessment

- Selection and definition of impact categories, indicators and models
- Classification (assignment of Inventory results to impact categories)
- Characterisation (modelling of the Inventory data within the impact categories with the aid of indicators per category: often called the Environmental Profile)
- Normalisation (relate the results of the Characterisation to reference values for e.g. an area and a time period such as the total emission in a country: often called the normalised environmental profile)

Classification and Characterisation



bre

Typical Impact Categories:

- Ozone Depletion
- Air pollution
- Global Warming
- Waste generation
- Water extraction
- Mineral extraction
- Water pollution
- Acid rain

Typical Impact Categories

- Fossil fuel use
- Mineral use
- Land use
- Water use

- Ozone depletion
- Global warming
- Acidification
- Eutrophication
- Human health
  (cancer, noncancer, etc.)

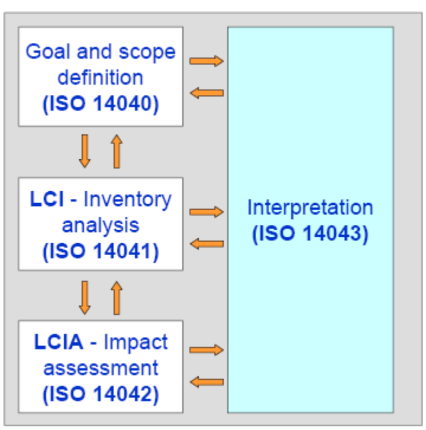
Ecotoxicity

FIRST ENVIRONMENT

Example of an environmental profile

indicator result (unit)	WWTP **A**	WWTP **B**
abiotic depletion (—)	40×10^{-10}	2×10^{-10}
global warming (kg CO_2)	80×10^{6}	5×10^{6}
human toxicity (kg b.w.)	30×10^{2}	4×10^{2}
aquatic ecotoxicity (m^3 water)	60×10^{7}	4×10^{7}
terrestric ecotoxicity (kg soil)	6×10^{7}	450×10^{7}
acidification (kg SO_2)	2×10^{5}	4×10^{5}
nutrification (kg PO_4^{3-})	3×10^{5}	16×10^{5}
fotoch. oxidant formation (kg C_2H_4)	14	15

Interpretation



Assessing whether results are inline with project goals, providing an unbiased summary of results, defining significant impacts and recommending methods for reducing environmental burdens

FIRST ENVIRONMENT

Interpretation

- Here the findings of either the inventory assessment or the impact assessment are evaluated in relation to the goal and scope in order to reach conclusions and recommendations

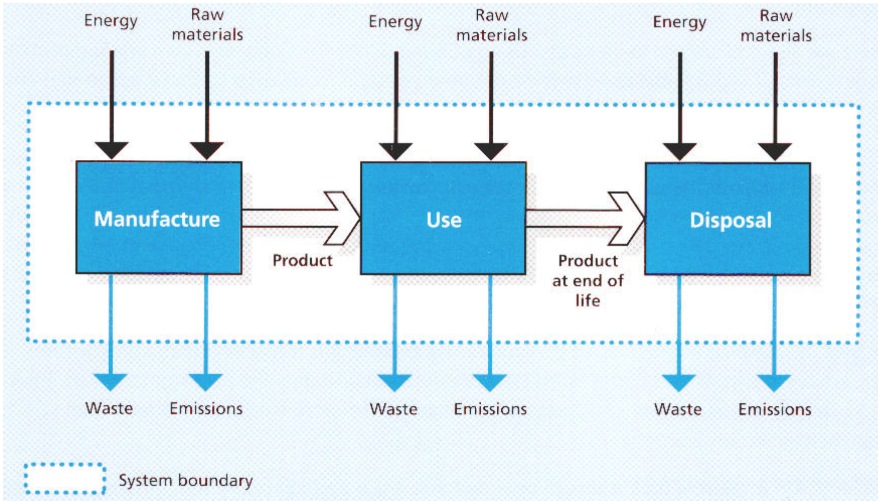
SUSTAIN

Because LCA embraces upstream and downstream factors
It should have spatial and temporal boundaries

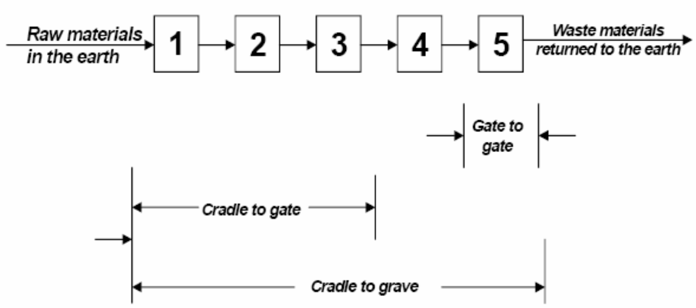
LIFE CYCLE BOUNDARIES

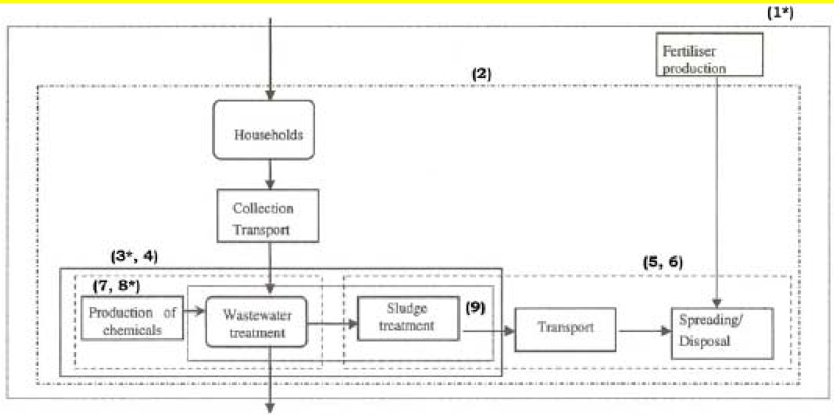
A **true life-cycle** always starts with the extraction of the raw materials from the earth and ends with the final disposal of the refusals in the earth

In practice **EVERY system** can be described, but if the described system do not satisfy the condition illustrated above, it does not represent an LCA but an eco-balance or an eco-profile



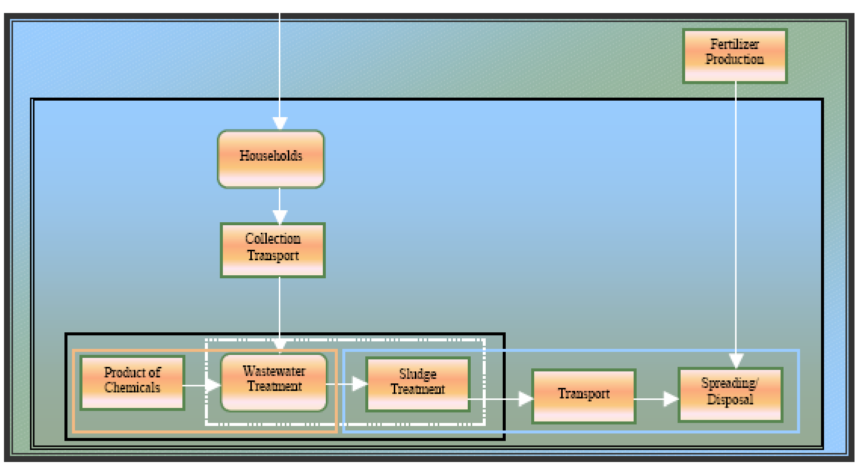
LIFE CYCLE BOUNDARIES
some definitions





Adapted from Lundin, Bengtsson, and Molander (2000)

Figure 4-1
A Simplified Sketch of Parts of a Wastewater Treatment System, Showing Different Ways To Draw System Boundaries



Functional unit

- Most important element in LCA study.
- Is the measure of performance which the system delivers.
- It can be the amount of product, material or service for which the environmental loadings are quantified.
- Should be clearly defined, measurable, and relevant to input and output data.

Life cycle assessment of wastewater treatment technologies treating petroleum process waters

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2.2.2. Functional unit

The functional unit is a measure of the performance of the product system. The primary purpose of the functional unit is to provide a reference to which the inputs and outputs are related and is necessary to ensure comparability of results.

A process water flow of 10,000 m^3/day for a time period of 15 years (system design life) was used in the present study in order to compare the different wastewater treatment processes. It is estimated that the

Definition of the functional unit:

Wastewater treatment system to treat the wastewater produced by 1 PE during 1 year

1 PE =
- 57 g BOD_5 /d
- 116 g COD /d
- 13g N /d
- 3 g P/d

	IN	OUT	limits today	limits future
Flowrate	100 000 m^3/d	70 000 m^3/d		
COD	270 mg/L	43 mg/L	90 mg/L	90 mg/L
BOD_5	133 mg/L	14 mg/L	25 mg/L	25 mg/L
SS	133 mg/L	14 mg/L	35 mg/L	35 mg/L
NTK	31 mg/L	17 mg/L	20 mg/L	10 mg/L
Nitrates	0 mg/L	4 mg/L		
Ptotal	7 mg/L	5 mg/L		1 mg/L

ESU-services
environmental consultancy for business and authorities

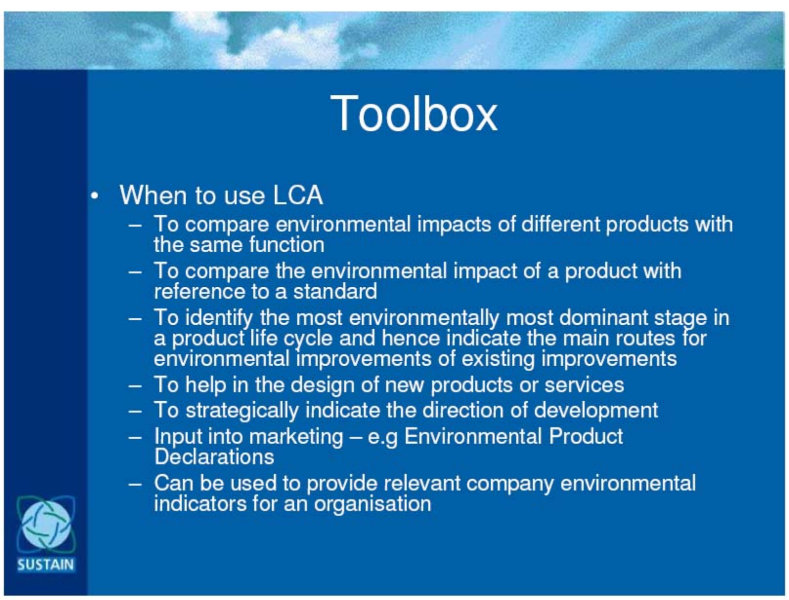
Information sources

LCI information sources are

- Individual questionnaires (written documents)
- Individual interviews (face2face, via phone)
- Environmental reports (of individual sites, entire companies, associations) and EPDs
- Reference works and statistics (published by national or regional authorities)
- Specific LCIs / LCAs (e.g., APME plastics, EAA aluminium)
- Well documented LCA case studies
- LCA mailing lists and fora; internet

www.esu-services.ch

LCA in Practice, A Decision Making Tool, Some case studies



Advantages

- Holistic view
- Prevents burden shift
- It deals with complexity rather than ignoring it
- Very good at assessing global and regional environmental impacts
- Brings objectivity to impact assessments
- Manages subjectivity
- Identifying and monitoring improvements
- Still developing

SUSTAIN

Common Sense

Which Product Would You Choose?

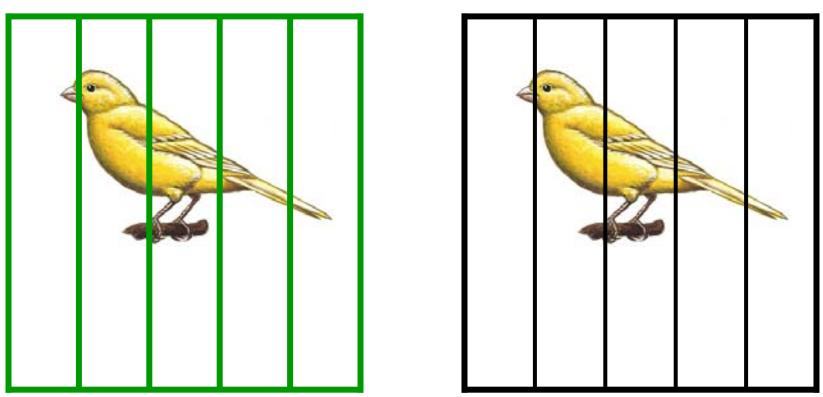


Table 1: Various wastewater treatment alternatives

Alternative – I	Physio-Chemical Treatment (PCT)+ Activated Sludge Process (ASP) + Chlorination
Alternative – II	Physio-Chemical Treatment (PCT)+ Activated Sludge Process (ASP) + Waste Stabilization Pond (WSP)
Alternative – III	Pre-settler (PS)+ Upflow Anaerobic Sludge Blanket (UASB) Reactor + Activated Sludge Process (ASP) + Chlorination
Alternative – IV	Pre-settler (PS)+ Upflow Anaerobic Sludge Blanket (UASB) Reactor + Activated Sludge Process (ASP) + Waste Stabilization Pond (WSP)
Alternative – V	Upflow Anaerobic Sludge Blanket (UASB) Reactor + Waste Stabilization Pond (WSP)
	Waste Stabilization Pond (WSP)
Alternative – VII	Anaerobic lagoon (AL) + Waste Stabilization Pond (WSP)

Table 2: Life Cycle considerations factors on various wastewater treatment alternatives

Life cycle impact and other factors	Wastewater Treatment Alternatives (I to VII)						
	PCT + ASP+ Chlorination (I)	PCT + ASP+ WSP (II)	PS+ UASB +ASP+ Chlorination (III)	PS+ UASB+ ASP + WSP (IV)	UASB + WSP (V)	PCT + AL+ASP+ WSP (VI)	AL + WSP (VII)
Chemical requirement	High	Medium	Medium	No	No	Medium	No
Energy requirement	High	High	Medium	Medium	Low	High	Low
Green house gas emissions	Medium	Medium	Medium	Medium	Low	High	High
Sludge generation	High	High	Medium	Medium	Low	High	Low
Capital cost	Medium	Medium	High	High	Medium	Medium	Low
Land requirement	Low	Medium	Low	Medium	Medium	High	High
Chemical Hazard/ Risk	High	No	High	No	No	No	No

Comparative Study of Wastewater Treatment Facilities

investigated categories were: Abiotic Depletion Potential (ADP), Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Human toxicity Potential (HTP), Fresh water Aquatic EcoToxicity Potential (FAETP), Marine Aquatic EcoToxicity Potential (MAETP), Terrestrial EcoToxicity Potential (TETP), Photochemical Oxidation Potential (POCP), Acidification potential (AP), Eutrophication Potential (EP), Impact of Ionizing Radiation (IIR), Final Solid Waste (FSW). Furthermore there was looked at the use of land area of both

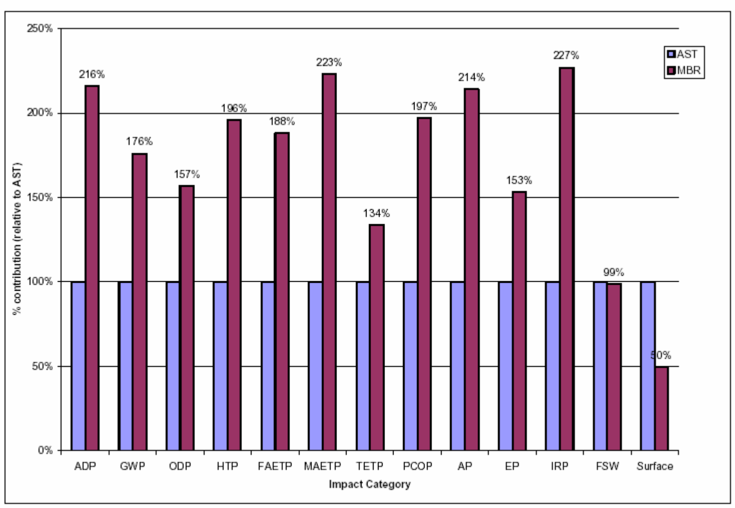


Figure 0-1: Percentual comparison of the contributions to the categories for the two alternatives (MBR v.s. AST)

Implementation of LCA on a wastewater treatment plant

- preliminary results-

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Laboratoire des Sciences du Génie Chimique, Nancy, France

2 goals:

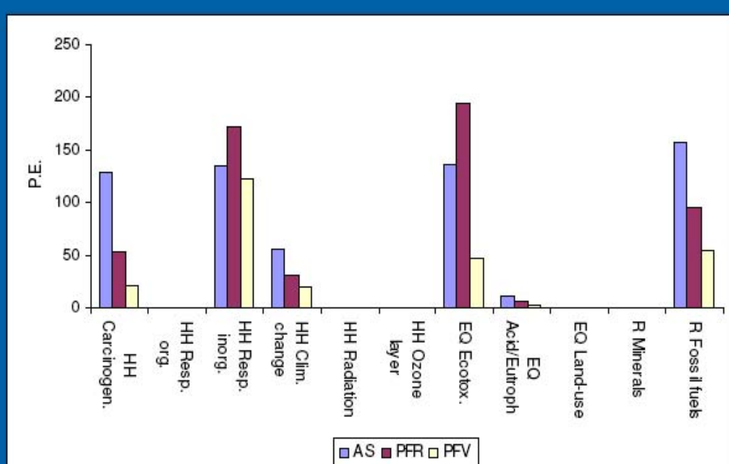
- Test of WG5 reference scenario with "LCA spirit"
- Test of implementation of LCA on a WWTP (WG3)

LCA

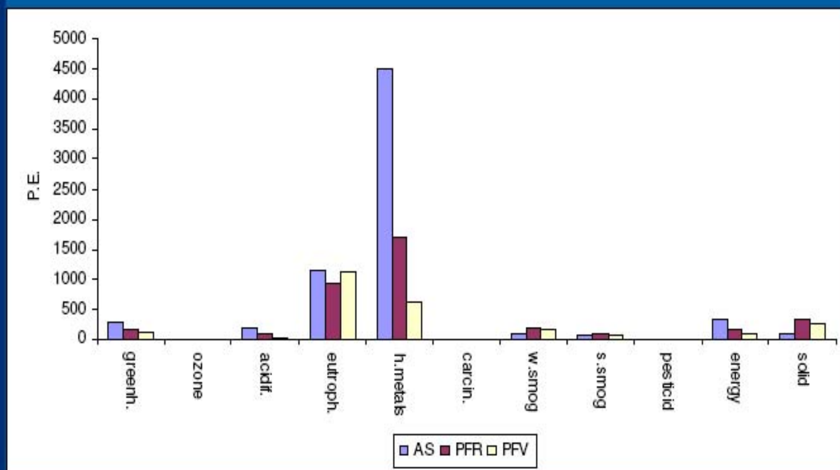
- -> data collection problem
- -> compromise

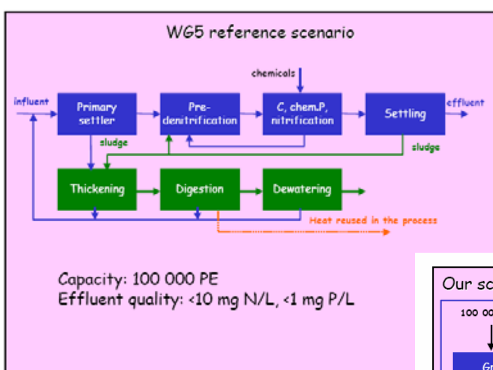
LSGC CNRS ENSIC inpl

LCA Comparison for Wastewater Treatment Work EI99

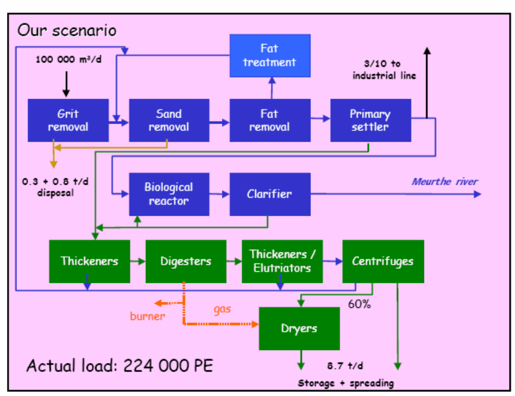


LCA Comparison for Wastewater Treatment Works – EI95





The Use of LCA To Compare Between Scenarios

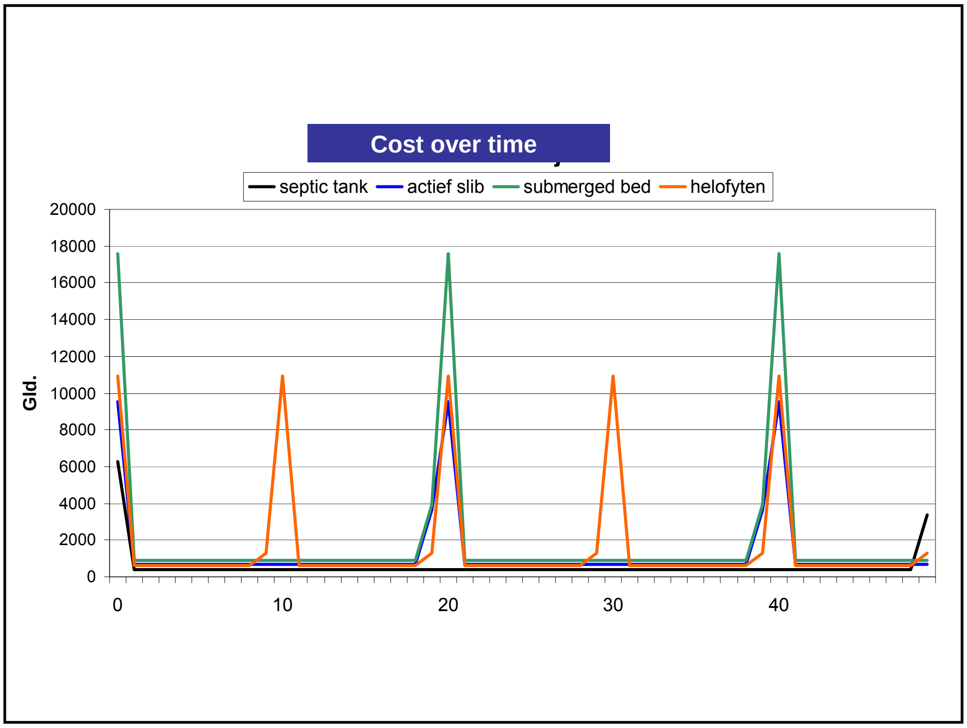


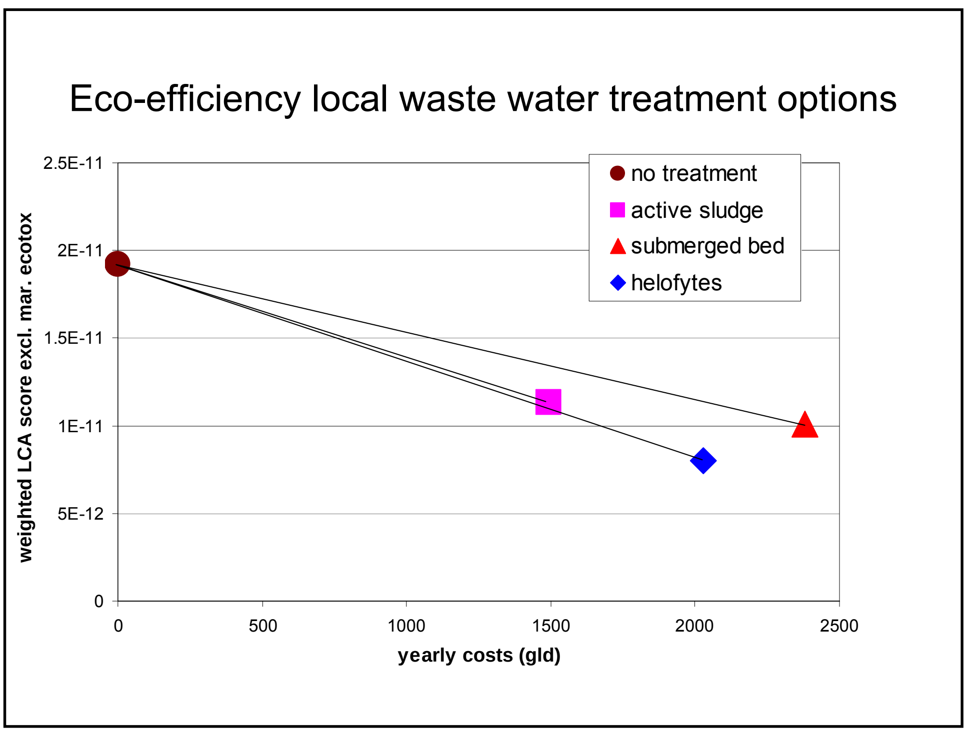
LCA
= Comparison of different scenarios

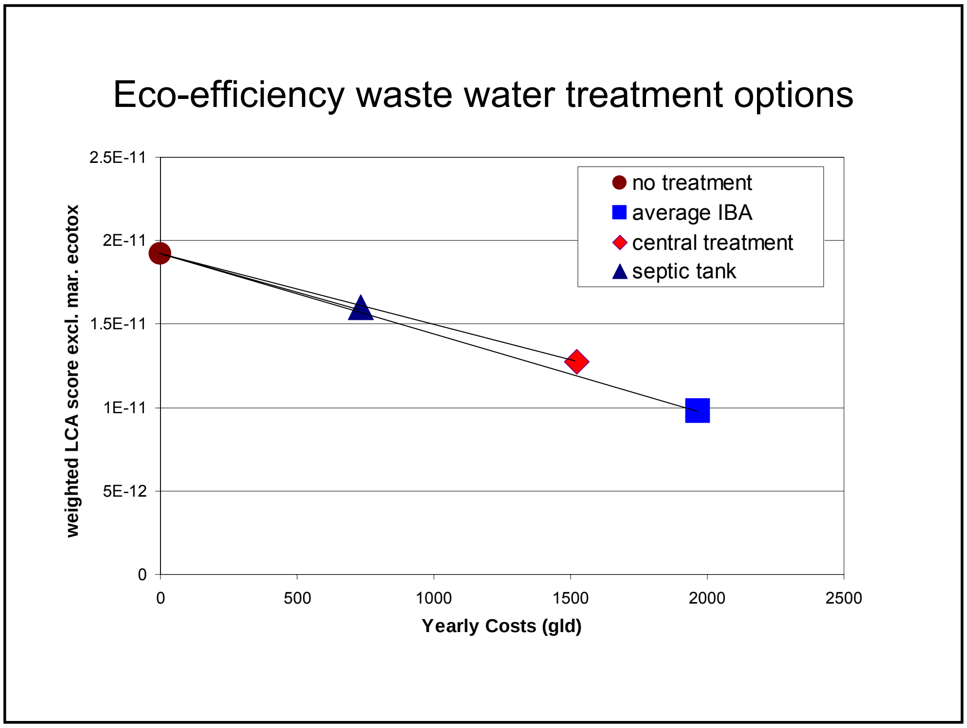
- Scenario 1: actual plant
- Scenario 2: effect of an anoxic zone in the biological reactor
    - improvement of nitrogen treatment
    - effect on energy balance

What is the best choice for the anoxic zone (volume)
at constant total volume
& no external carbon source
Best Available Technology (BAT)

Cost Versus Environment
An LCA Approach


Cost over time
septic tank
actief slib
submerged bed
helofyten
Gld.
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40


Eco-efficiency local waste water treatment options
no treatment
active sludge
submerged bed
helofytes
weighted LCA score excl. mar. ecotox
2.5E-11
2E-11
1.5E-11
1E-11
5E-12
0
0
500
1000
1500
2000
2500
yearly costs (gld)


Eco-efficiency waste water treatment options
2.5E-11
2E-11
1.5E-11
1E-11
5E-12
0
0
500
1000
1500
2000
2500
Yearly Costs (gld)
weighted LCA score excl. mar. ecotox
no treatment
average IBA
central treatment
septic tank


Thank you for your attention
The End