Education and Culture
Leonardo da Vinci

Sustainability in commercial laundering processes

Module 1
Usage of Water

Chapter 5

Waste water treatment Biological treatment

Content

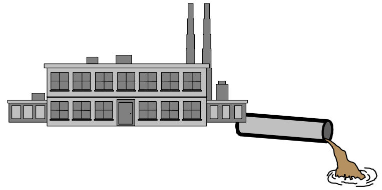
- Introduction
- Laundry-wastewater
- Microorganisms
- Wastewater installation engineering
- Examples of WWTP's in laundries

Learning targets

After finishing this chapter, you will

- Know the composition of waste water in laundries
- Know when and why waste water should be treated
- Know and be able to explain biological waste water treatment
- Know the role of microorganisms in biological waste water treatment process
- Know 4 different (biological) possibilities to treat waste water and be able to explain them
- Be able to point out the differences between the different processes

Why wastewater treatment in laundries ?

- Reduce environmental pollution 
- Reduce consumption of natural resources 
- Avoid disruption to natural circuits 

- Comply with licensing requirements and orders §
- Reduce costs $ £ €

Content:

Laundry wastewater contains substances mainly from 3 sources:

- Substances from the raw water (tap water, well, etc.)
  => salts
- Detergents
  => tensides, phosphates, silicates, etc.
- Dirt from the clothes
  => particles, fat, oil, colour, etc.

Important: limiting parameters for discharge?
=> e.g. P, AOX, heavy metals

Concentrations (3 examples of laundry wastewater):

Temp [°C]	35	41	36
pH	9,3	9,9	9,6
Conductivity [mS/cm]	1,7	3,0	2,4
COD [mg/l]	1.100	900	1.450
BOD_5 [mg/l]	n.n.	350	670
N,tot. [mg/l]	25	22	35
P,tot. [mg/l]	11	55	7

T Temperature (heat exchanger? Thermal or chemo-thermal disinfection?)

pH => Alkalinity !

COD „**C**hemical **O**xygen **D**emand" => parameter for the organic pollution

BOD_5 „**B**iochemical **O**xygen **D**emand" after 5 days
=> parameter for the biodegradable pollution

P,tot. Total Phosphorous (P-free detergents ?)

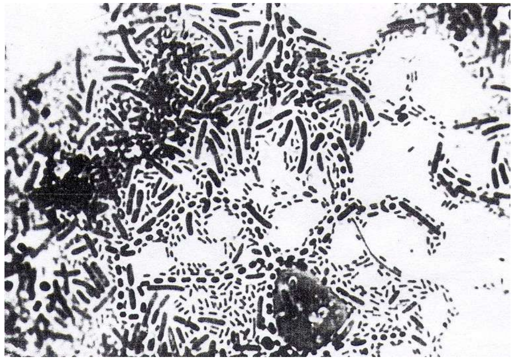
Other Contents:

- AOX (=> use of Chlorine in main wash ?)
- Heavy metals (=> textiles from metal working industry, kitchen wear)

What is biological wastewater treatment ?

Wastewater treatment with

- **Bacteria**
- Other Microorganisms
  (fungi, special processes only)



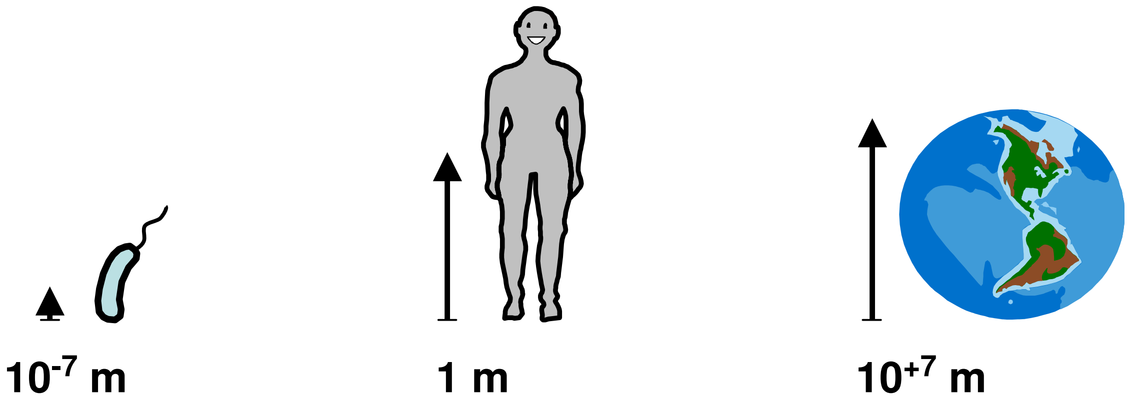
Picture of a typical bacteria community
from a municipal wastewater treatment plant

What is biological wastewater treatment ?

Wastewater treatment with

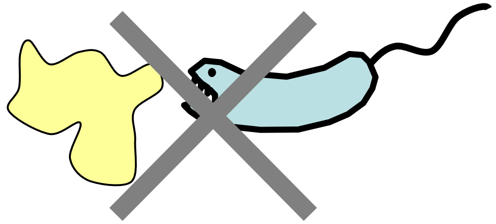
- Size of **Bacteria**: „*Micro* organisms“ => *micro* meter !

size-comparison bacteria – human beings – earth:



What can microorganisms do ?

- MO's do not „eat" the pollution

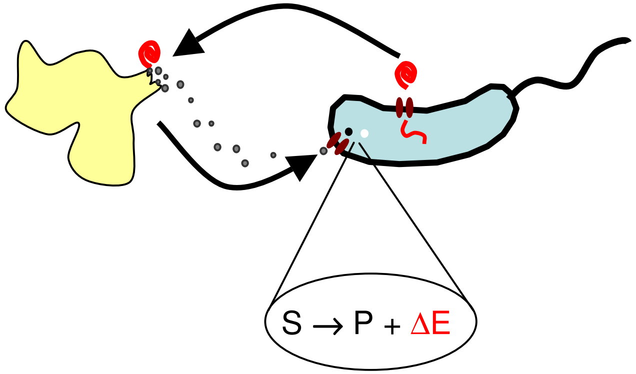


- MO's do wastewater treatment by conversions with **enzymes**

  S (Substrate, in ww-treatment the **pollution**)

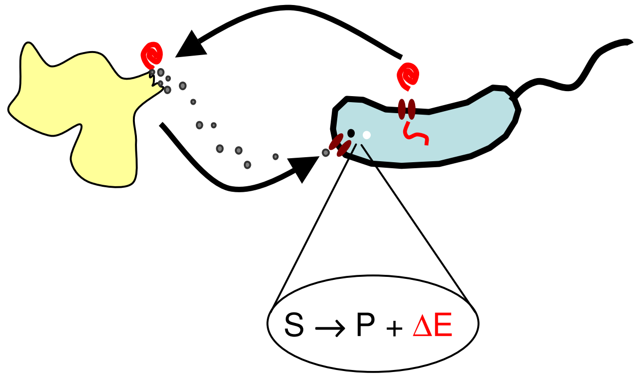
  => **P** (Product, CO_2, N_2, etc)

  \+ Energy (which is used for growing => surplus biomass !)



What can microorganisms do ?

- **Suitable conditions**:
  - MO‘s do the work for free
  - Often the only way for **cost-effective wastewater treatment**



Conversions by microorganisms

- **Aerobic** degradation of **organic pollutants** („COD, BOD_5“)

Org.Poll. + O_2 => CO_2 + H_2O

truly:

Org.Poll. + O_2 => CO_2 + H_2O **+ ΔE + Bacteria + residual Poll.**

- Surplus bacteria = up to 50 % of org.Poll. in municipal WW-treatment !
- Residual Pollution = usually 10-20 % of org.Poll. in municipal WW-treatment
  = 5-50 % in industrial WW-treatment (biodegradability !)
  = could be less than 5 % in laundry-WWTP‘s (good biodegr.)

Conversions by microorganisms

- **Degradation of nitrogen**

3 steps: **org.N** => NH_4

$NH_4 + O_2 \Rightarrow NO_3 + H_2O$

$NO_3 \Rightarrow N_2$

Conversions by microorganisms

- **Degradation of nitrogen**

3 steps: **org.N** $\Rightarrow NH_4$

~~org.C~~ $NH_4 + O_2 \Rightarrow NO_3 + H_2O$

$\cancel{O_2}$ **org.C** $+ NO_3 \Rightarrow N_2 + CO_2 + H_2O$

- 3 steps
- Total different conditions (org.C, O2) !

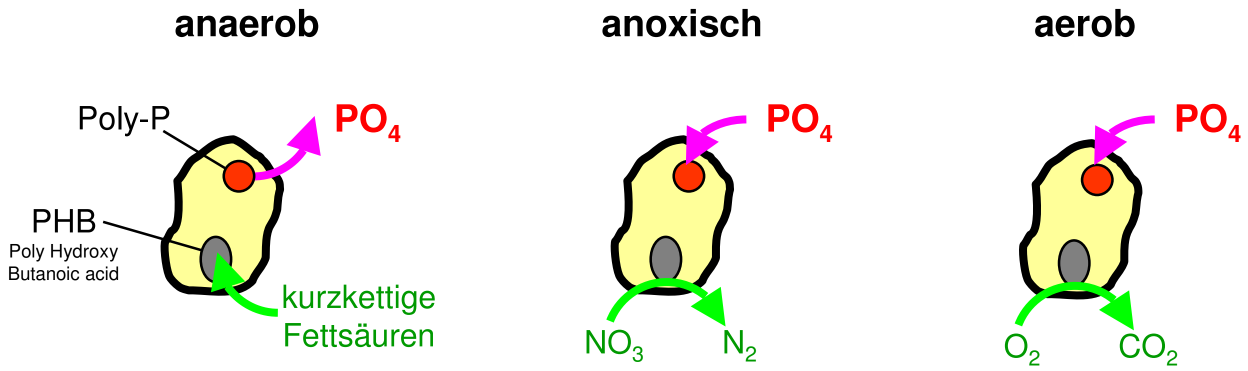
Conversions by microorganisms

- **Degradation of phosphorus**

… precipitation (non-biological, see below)

Conversions by microorganisms

- **Degradation of phosphorus** (biological way)



  - **Surplus P-uptake in bacteria, removal with surplus sludge** (P-removal from wastewater limited, different conditions, not easy to handle)

Conversions by microorganisms

- **Anaerobic degradation of organic pollutants**

Org.Poll. => CH_4 + CO_2

- No aeration
- High-energetic product (burning => energy, electricity)
- Considerably less surplus sludge

- High substrate concentrations (COD > 10.000 mg/l)

- Used in anaerobic sludge stabilisation

Conversions by microorganisms

- **Anaerobic degradation of organic pollutants**

Org.Poll. => CH_4 + CO_2

- Truly:

Org.Poll. => (Hydrolysis) => fragments, diluted Poll.

=> (Acidification) => H_2 + CO_2 + organ. Acids + Alcohol

=> (Acetogene) => H_2 + CO_2 + Acetic Acid

=> (Methanogene) => **CH_4 + CO_2**

- 4 steps
- 4 different MO-species
- Stable conditions important (temperature, product-concentrations)

Conversions by microorganisms

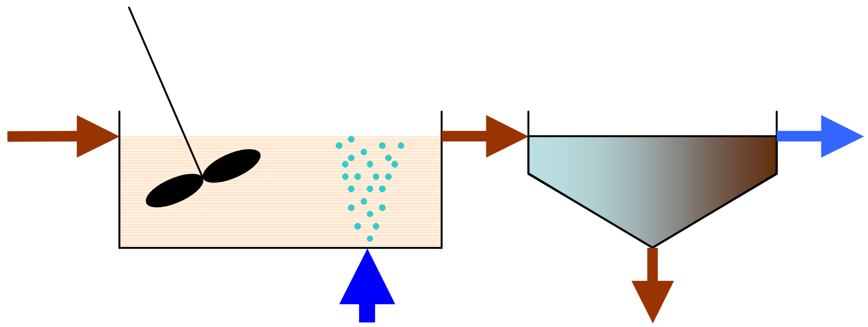
- **Degradation of persistant pollutants** (oil, fat)

1. undissolved Poll. + bio-tenside => micro drops
   => uptake into the Cell

2. conversion:
   CH_3-CH_2-CH_2-CH_2-CH_3 => CH_3-CH_2-CH_2-CH_2-CH_2OH
   => CH_3-CH_2-CH_2-CH_2-$COOH$
   => CH_3-CH_2-CH_3 + CH_3-$COOH$

Principle: **bad** biodegradable ➔ **good** biodegradable
- by formation of --COOH
- by separation of C_2-fragments (acetic acid, => citric cycle)

Construction of WWTP‘s:



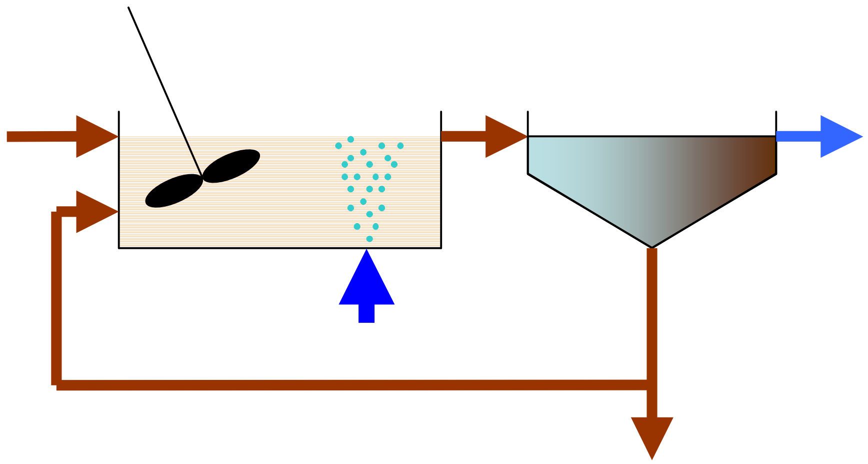
- **Diluted**
- Fixed bed
- Constructed wetlands
- Combinations

Very simple process
Low maintenance
For low and medium polluted WW

MO‘s could be washed out

Construction of WWTP‘s:

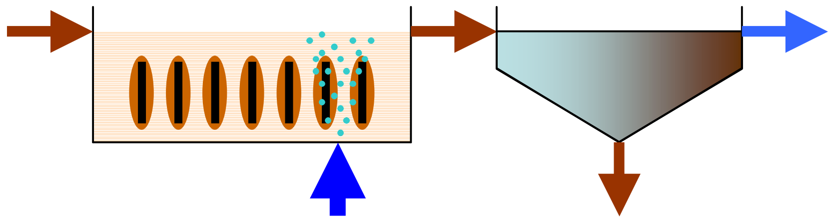
- **Diluted**
- Fixed bed
- Constructed wetlands
- Combinations



- **„activated sludge process“**
- Recirculation of the MO‘s =>(higher MO-concentration for better removal rates)

Construction of WWTP‘s:

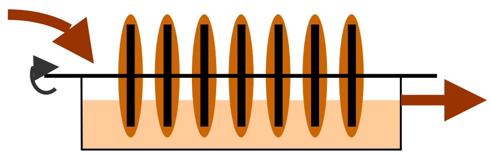
- Diluted
- **Fixed bed**
- Constructed wetlands
- Combinations



MO‘s fixed
no wash out
higher flow rate
Biofilm less sensitive
Less surplus sludge

MO-separation also required

Construction of WWTP‘s:



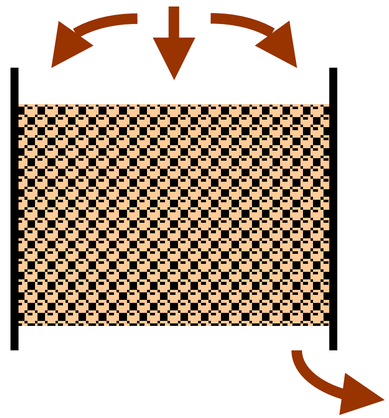
- Diluted
- **Fixed bed** - rotating disk reactor
- Constructed wetlands
- Combinations

MO‘s rotate
Alternating Contact air / WW
No aeration required
Less energy consumption

„tube-reactor“ (no dilution of toxic load)

Construction of WWTP‘s:

- Diluted
- **Fixed bed** - trickling filter
- Constructed wetlands
- Combinations

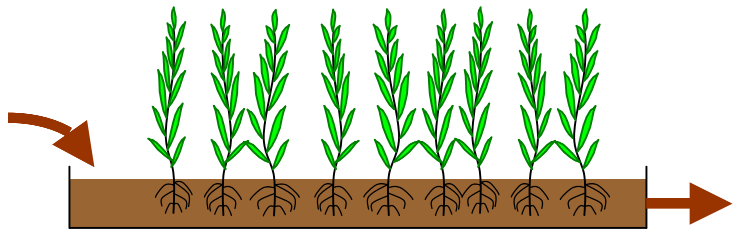


MO‘s at packing material (e.g. lava)
WW „trickles“
No aeration required
Low energy consumption

2nd step in N-degradation

Construction of WWTP‘s:

- Diluted
- Fixed bed
- **Constructed wetlands**
- Combinations



Treatment by MO‘s in root area
treatment also in winter time (ca. 80 %)
O_2 supply by the plants (e.g. reed)
Beautiful optical appearance („ecological“)

High space requirement
Accumulation of toxic substances possible (in soil area)

Construction of WWTP's:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  biological - chemical

UV, H_2O_2, Ozone
- Oxidation of persistent substances
- Detoxification
- Increase of biodegradability

- High energy consumption
- Chemicals must be added

Construction of WWTP's:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  biological - chemical

Precipitation
Flocculation
Flotation

- Removal of non-biodegradable components
- Additional solid-liquid-separation

- Chemicals to be added
- …waste disposal !

Construction of WWTP‘s:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  biological - chemical

Precipitation

e.g. P-Elimination in WW-treatment
(Fe-III-salts, Al-salts)

Principle:
Formation of low soluble components & sedimentation or separation

Examples:

P-Elimination: $PO_4^{3-} + Fe^{3+} \Rightarrow FePO_3 \downarrow$

Metal-Elimination: $Fe^{3+} + 3\ OH^- \Rightarrow Fe(OH)_3 \downarrow$
$Cu^{2+} + 2\ OH^- \Rightarrow Cu(OH)_2 \downarrow$
(increase pH)

Construction of WWTP's:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  biological - chemical

Flocculation

Additional separation of MO's from treated water

Problem:
- Settling velocity of small MO-flocs or single MO's too low for technical application

- Settling velocity = *f* (particle diameter)^2

Principle:
- Small flocs or single MO's are coalesced by flocculation agents (organic, synthetic, high molecular and water soluble poly-electrolytes, Fe(III)-salts, …)

- Increase of floc-size => increase of settling velocity
- Better sludge-drainage

Construction of WWTP's:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

Biology & Filters

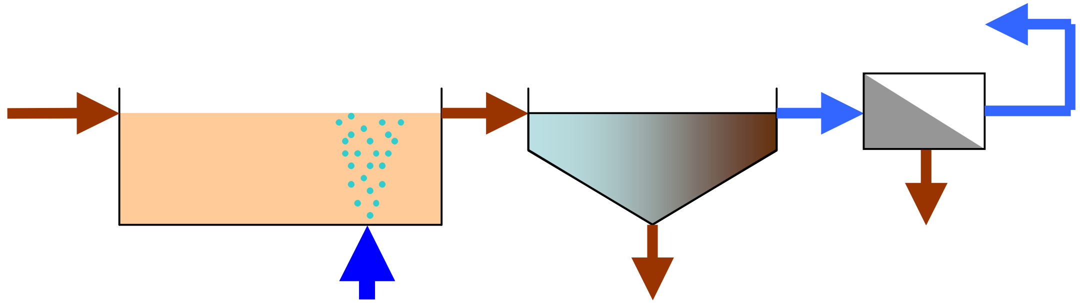
e.g. sand filter

- For supplement sludge separation
- Better effluent quality
- Separation of single MO's
- Adsorption

Construction of WWTP‘s:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  Biology & Membranes

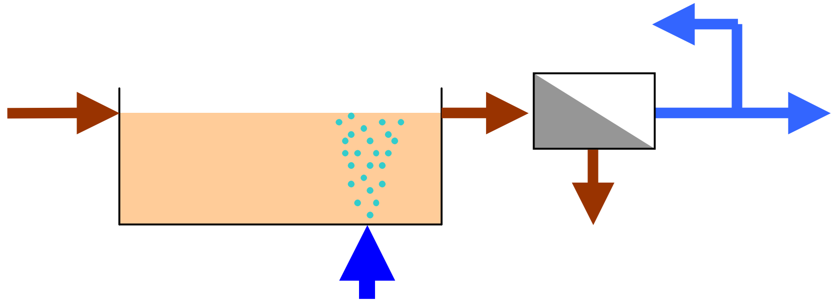


Wastewater Recycling
=> Germfree effluent
=> Elimination of residual pollution
=> Elimination of heavy metals
=> Elimination of salts

Construction of WWTP's:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  Biology & Membranes



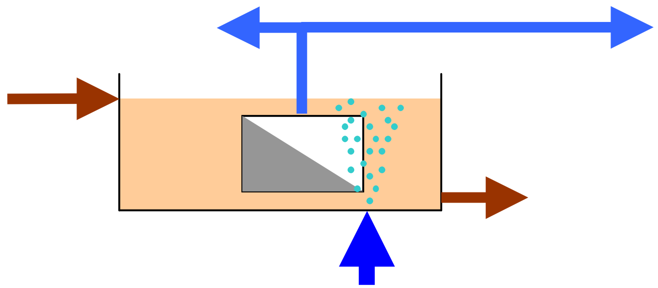
Alternative for sedimentation tank
- external arrangement

=> Germfree effluent
=> Elimination of residual pollution
=> Less space requirement
=> modular
=> Recycling of process water

Construction of WWTP‘s:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

  Biology & Membranes



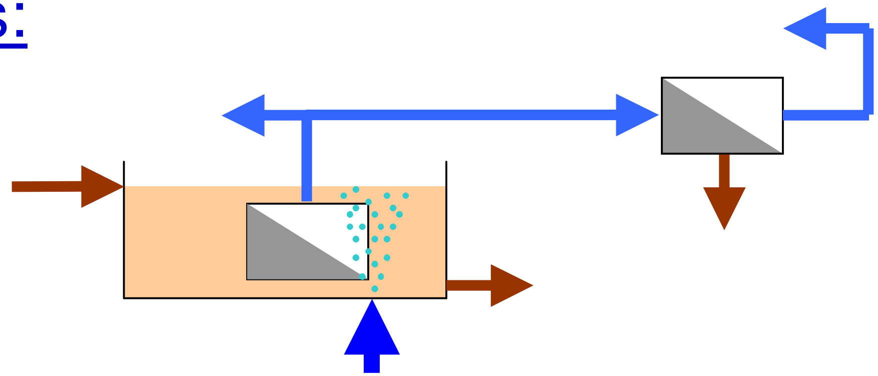
Alternative for sedimentation tank
- internal arrangement

=> Germfree effluent
=> Elimination of residual pollution
=> Less space requirement
=> modular
=> Recycling of process water
=> MO‘s stay in the reactor (spezialised MO‘s)

Construction of WWTP's:

- Diluted
- Fixed bed
- Constructed wetlands
- **Combinations**

Biology & Membranes



Combination of membranes

=> Recycling of process water
=> Additional elimination of salts and other pollutants

WWTP's **in laundries**

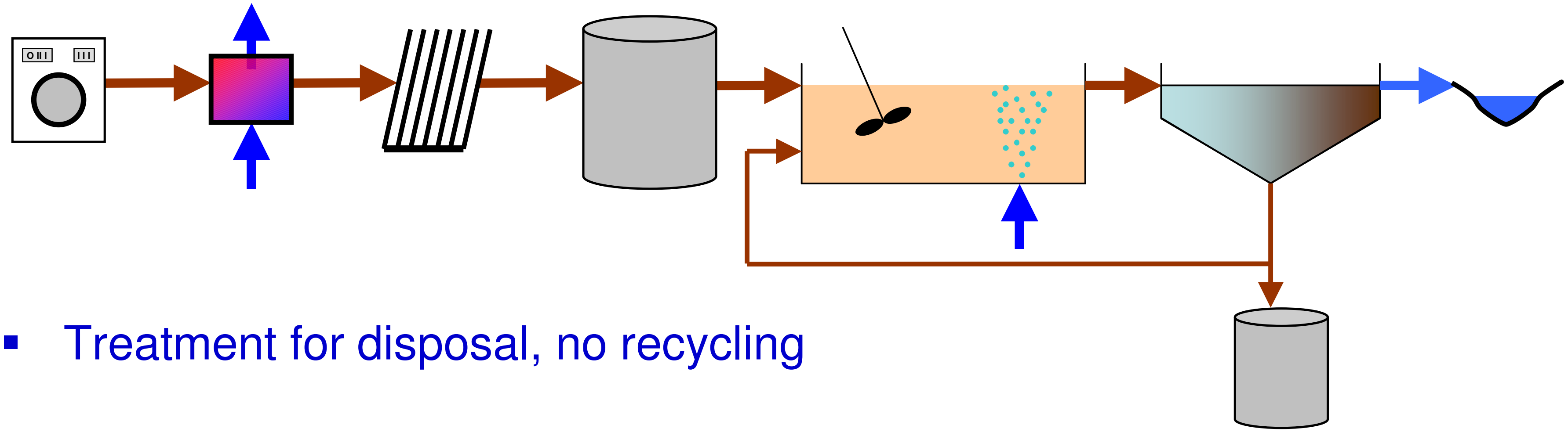
- All solutions are applicable depending on problem & situation

- No continuous WW feed
  - requires storage tank

- Self-monitoring, maintenance & repair
  - Manpower requirement
  - Manpower with „keen sense for the plant"

- Cost accounting
  - Economy of operational costs „not worldshaking"
  - Investment relatively high (=> long payback period)

WWTP - Example 1:



- Treatment for disposal, no recycling
    - 700-800 m^3/d
    - 3000 EW
    - COD-Elimination > 93 %
    - Disposal in river
    - Reduction of operational costs 50 %

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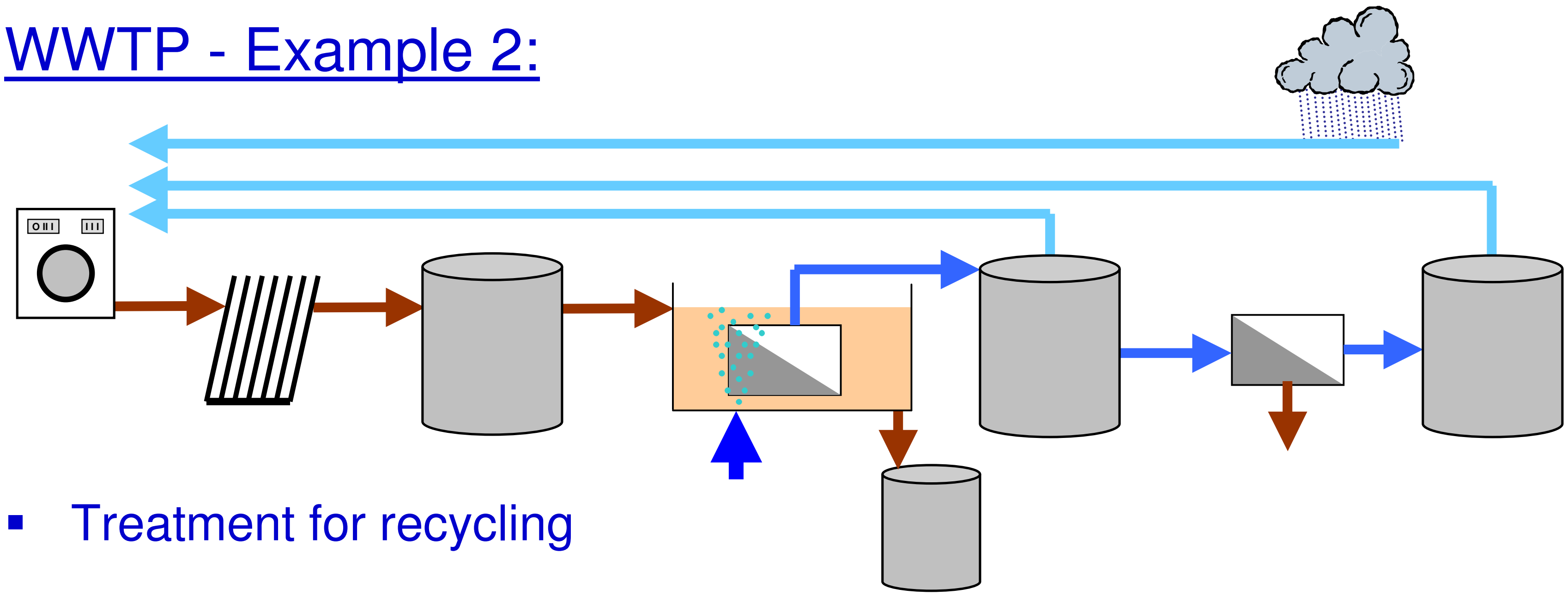
WWTP - Example 2:



- Treatment for recycling
  - 150 m^3/d
  - 2000 EW
  - COD-Elimination > 96 %
  - Disposal in municipal sewer system
  - Reduction of operational costs 50 % & recycling