

# ENV-405 Session 2

## Wastewater treatment

### Lecture 5 Dec 2

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Slides acknowledgment: Christof Holiger

# Today's content:

## Design of Biological Aerated Filters (BAF)

- – case study **Bern WWTP**

## Expansion and Modernization of the Biological Treatment

# Major Attached-growth System Types (there're other variations)

System Type	Full Name	Media Condition	Primary Applications	Examples / Notes
<b>Trickling Filter (TF)</b>	Trickling Filter	Unsaturated (air-filled) fixed-film	BOD removal	Classic stone/plastic media towers; natural ventilation or forced draft
<b>Rotating Biological Contactor (RBC)</b>	Rotating Biological Contactor	Rotating discs alternately in air and wastewater	BOD removal, nitrification	Energy-efficient; low maintenance
<b>Biological Aerated Filter (BAF)</b>	Biological Aerated Filter	Submerged, aerated fixed-film + filtration	BOD removal, nitrification, denitrification	<b>BIOSTYR (Veolia), BIOFOR (SUEZ)</b>
<b>Moving Bed Biofilm Reactor (MBBR)</b>	Moving Bed Biofilm Reactor	Submerged, free-moving plastic carriers	BOD removal, nitrification; retrofits	Not a classic "biofilter," <b>Hybrid</b>

# Biological Aerated Filters (BAF)

- Biofilter is a very efficient WWT in terms of footprint and treatment efficiency. Relatively “novel” compared to activated sludge.
- Right now two common processes on the market (other variations exist)

BIOSTYR™ Véolia

BIOFOR® Suez environnement -Degrémont

# Comparison: Area / Volume

- **Area**

m<sup>2</sup>/PE  
population equivalent

%

Activated Sludge

7.4

740

Biofilter

1.0

100

Moving Bed

3.6-4.3

360-430

- **Volume**

Tank volume/PE

%

Activated Sludge

260

325

Biofilter

80

100

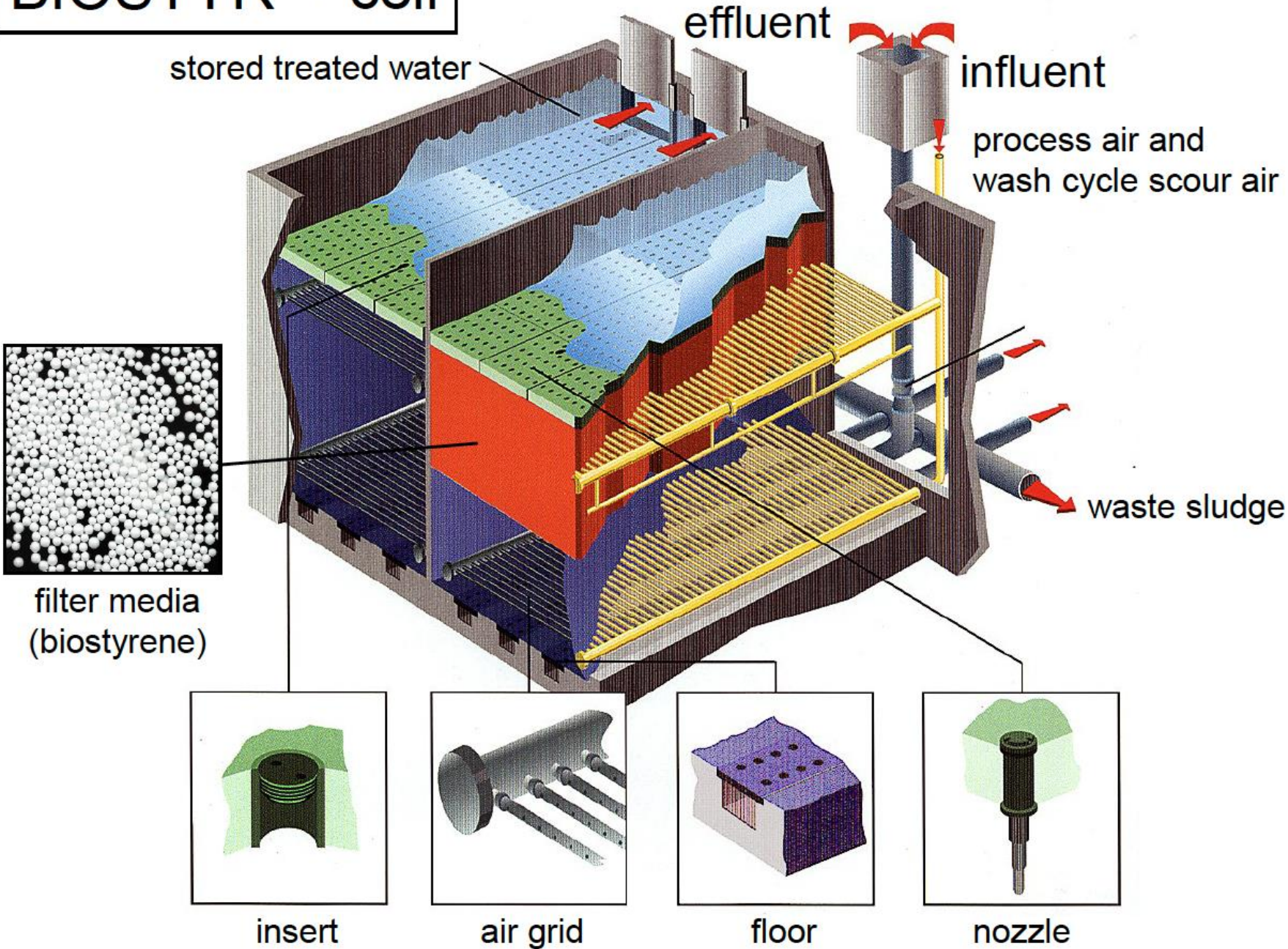
Moving Bed

125-150

160-190

Because of the reactor shape, part of the reactor can go underground. It's very area/footprint-saving. Volume is also smaller than others.

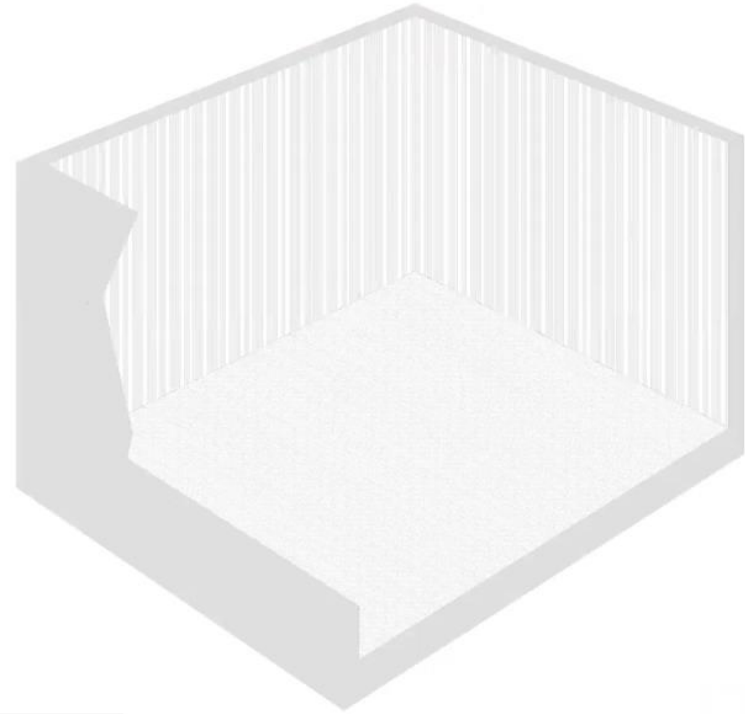
# BIOSTYR™ cell



- Always need to have at least 2 unit: the filters need to be regenerated.
- Discharge water is similar to effluent of secondary sedimentation.
- The biomass is retained/accumulated in the filters.

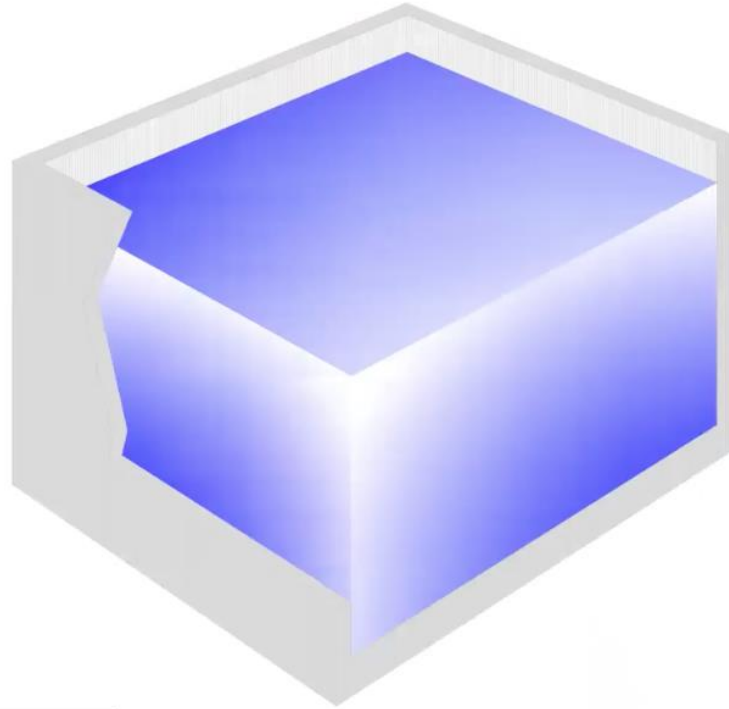
# BIOSTYR™ cell construction

Empty Biostyr cell

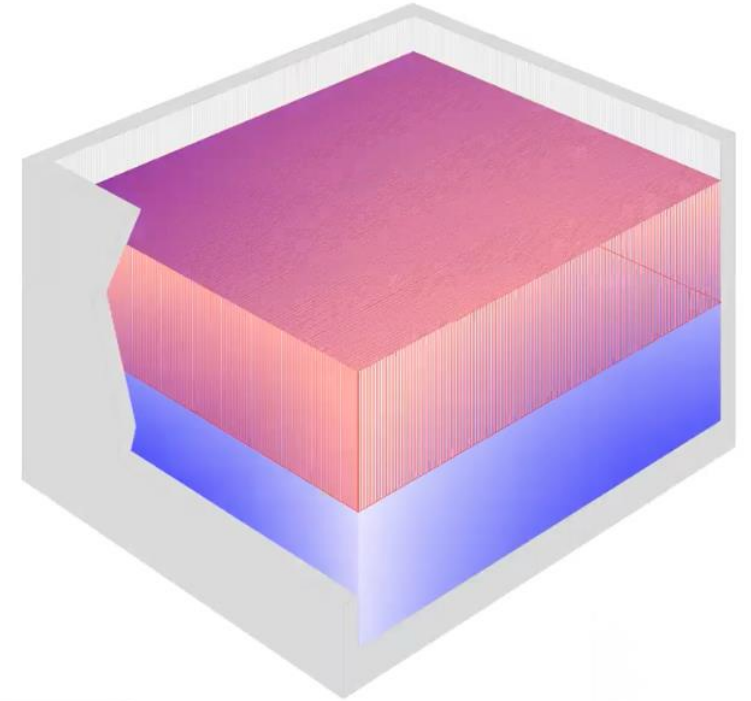


concrete

Biostyr cell filled with water



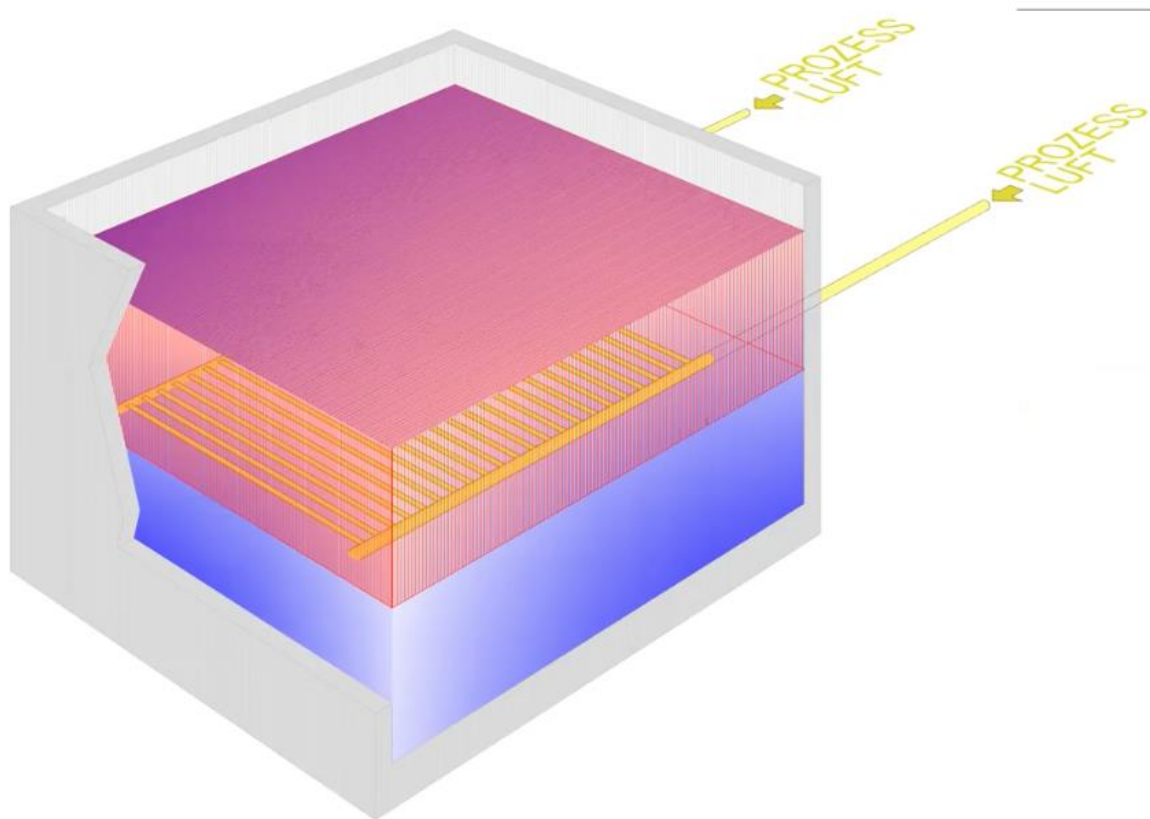
Biostyr cell filled with water and polystyrene beads



PS is lighter than water, even when covered by biofilms.

Aeration grid is for aeration for BOD removal and nitrification, it is also used for wash/maintenance (stronger aeration needed). Overall aeration is more energy intensive than other techniques.

Aeration grid in Biostyr cell

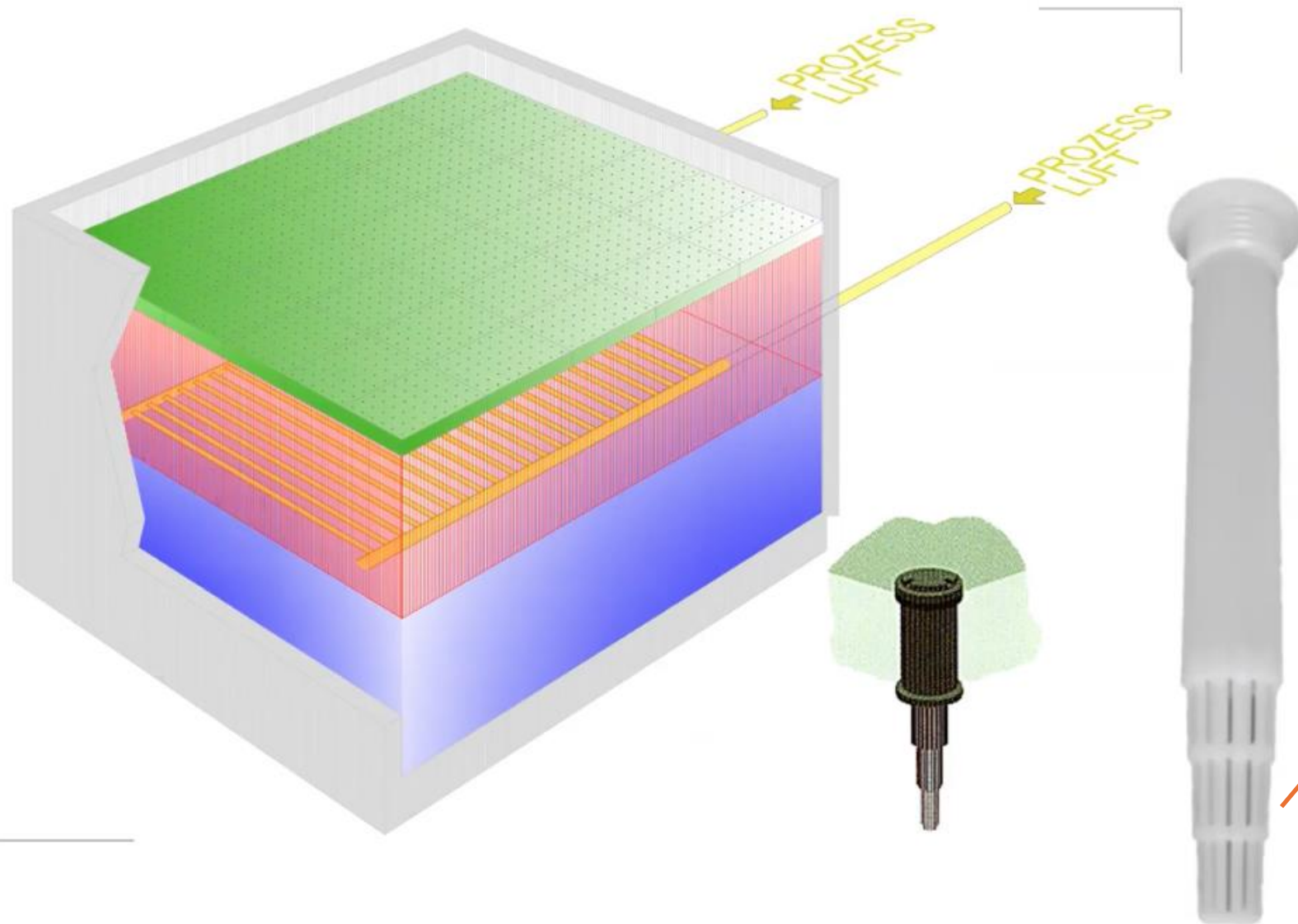


Can choose to do predenitrification.

Below aeration grid can be anoxic for denitrification. Can calculate where to put the aeration grid (how much is anoxic).

Then need another grid on the floor for the washing.

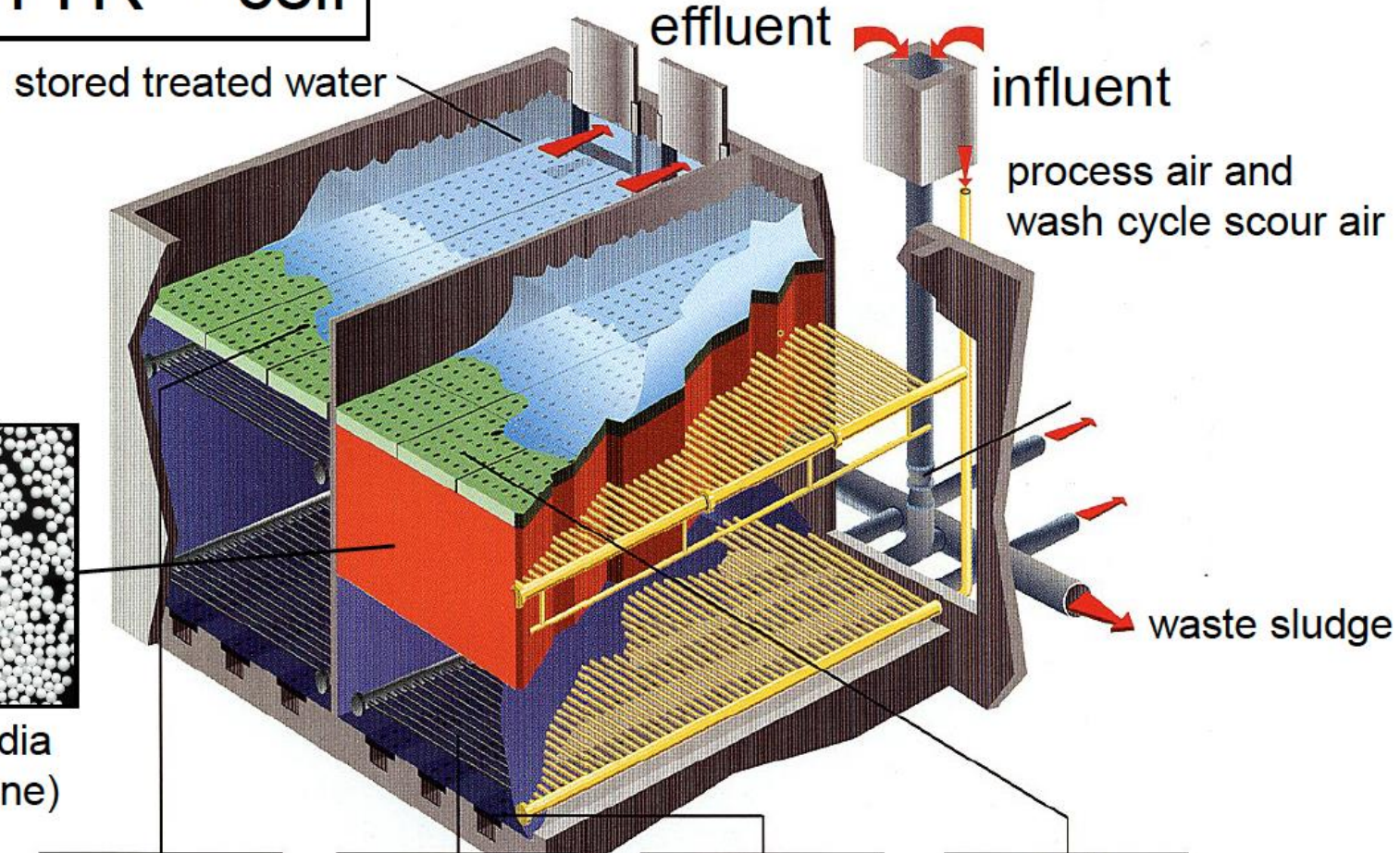
# Biostyr cell covered with floor containing filtration nozzles



Small opening at the bottom: water flow through but not biofilms.

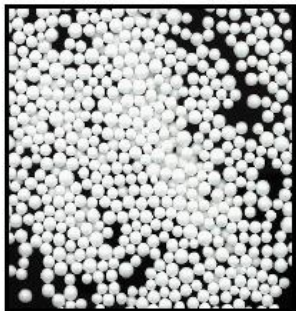
After some time, it will get clogged, need replacement.

# BIOSTYR™ cell

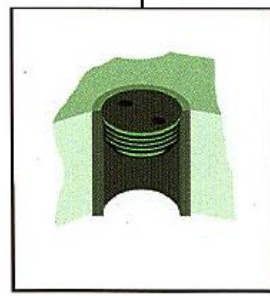


3-4 mm in diameter beads

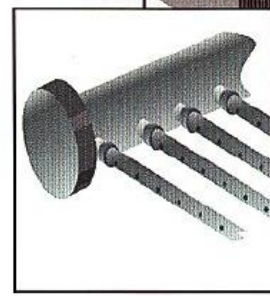
Also act similar to sand filters to retain particles.



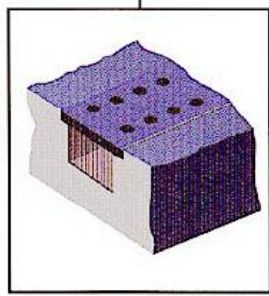
filter media (biostyrene)



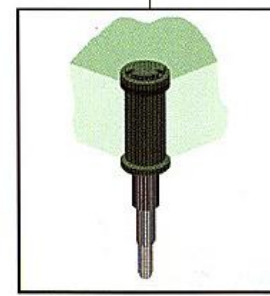
insert



air grid

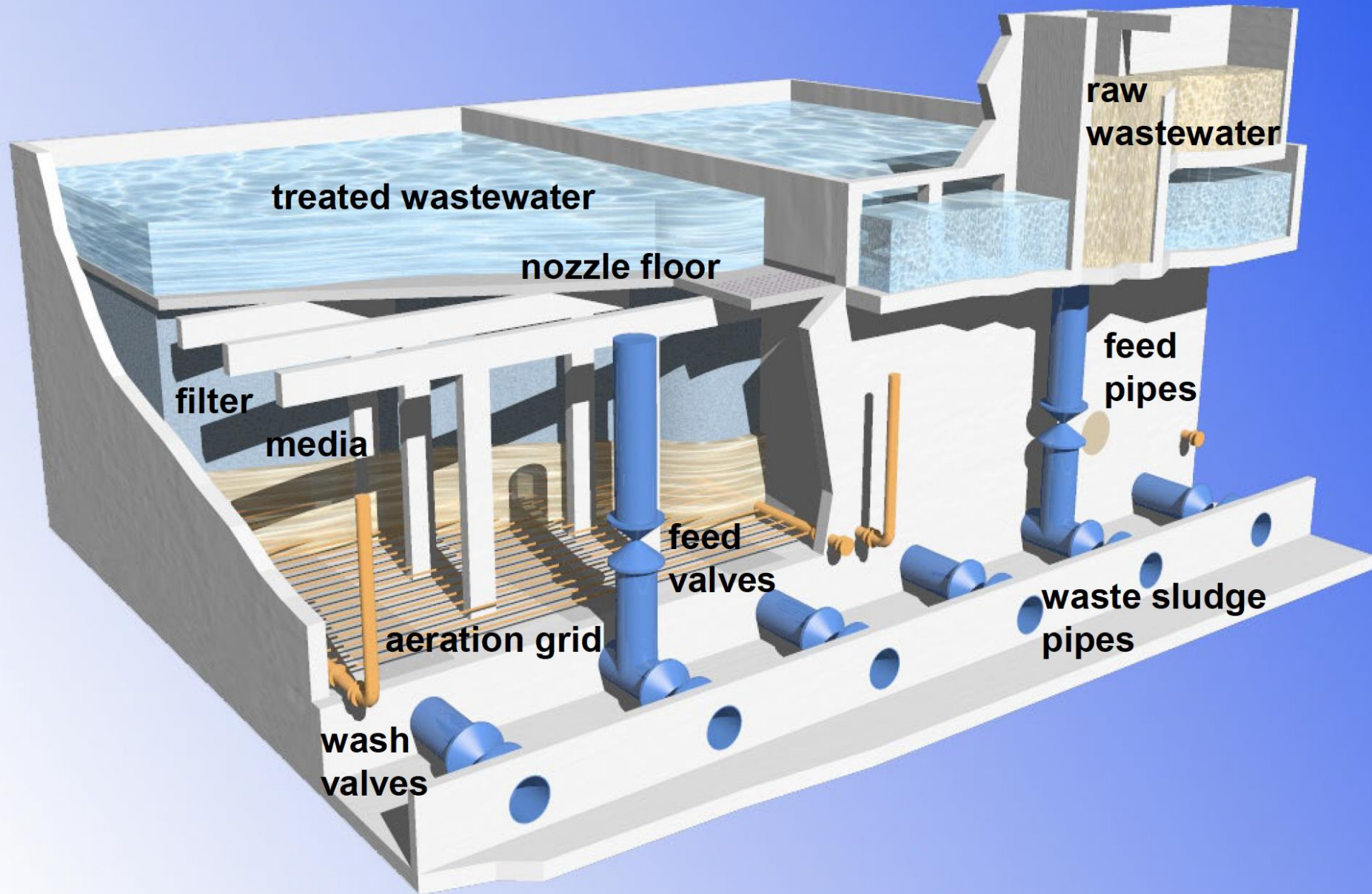


floor



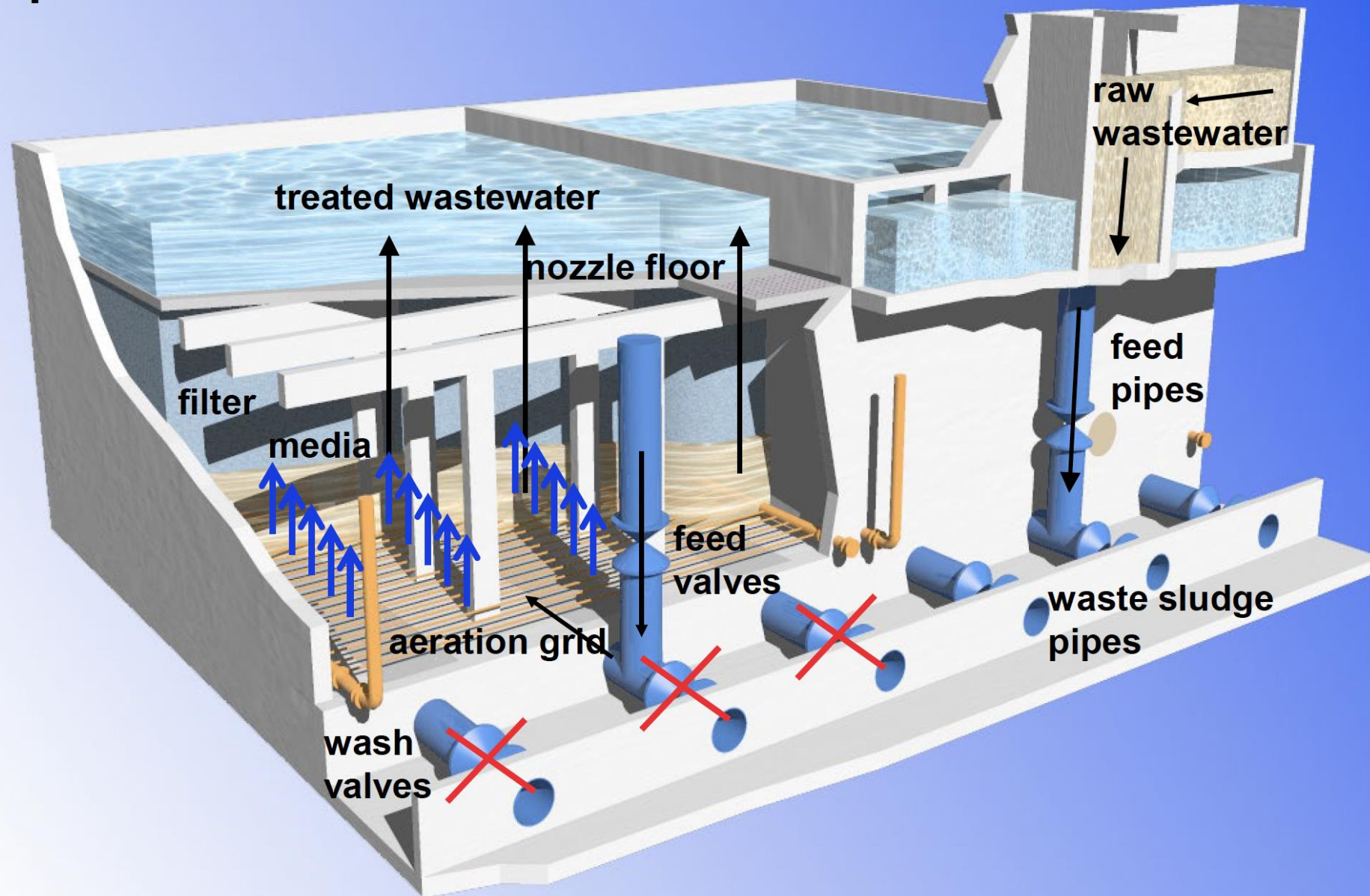
nozzle

# CONCEPT of Biostyr®



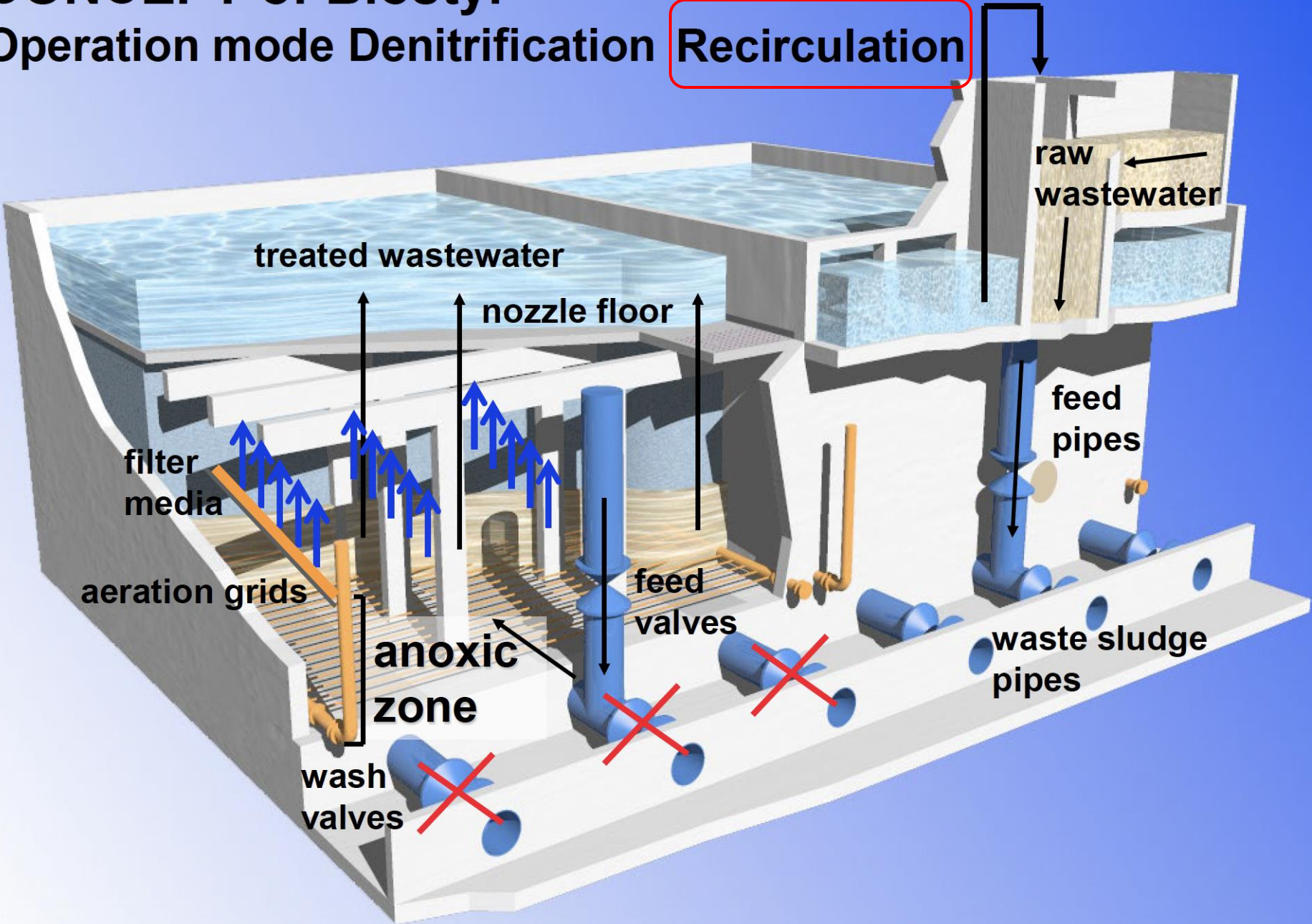
# CONCEPT of Biostyr<sup>®</sup>

Operation mode C and N oxidation



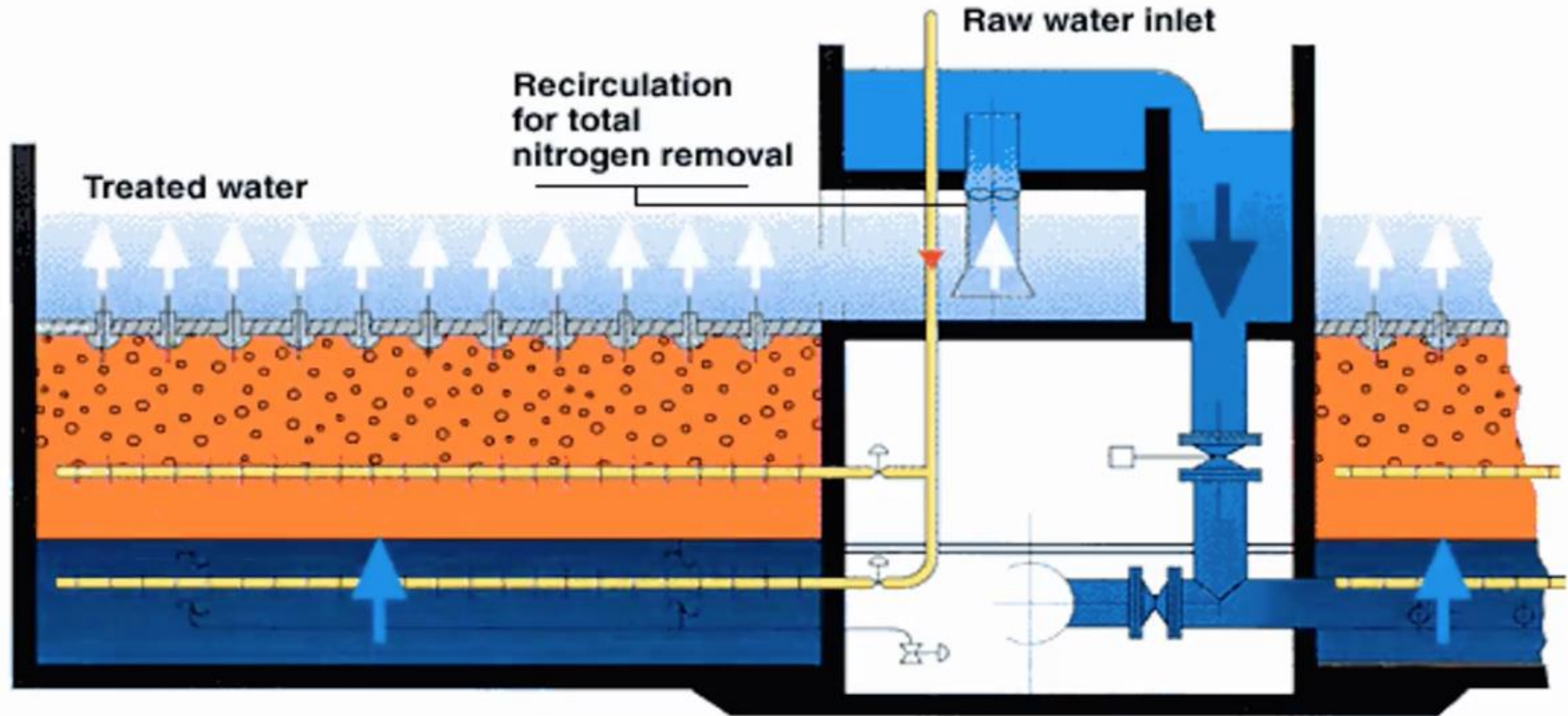
# CONCEPT of Biostyr<sup>®</sup>

Operation mode Denitrification **Recirculation**



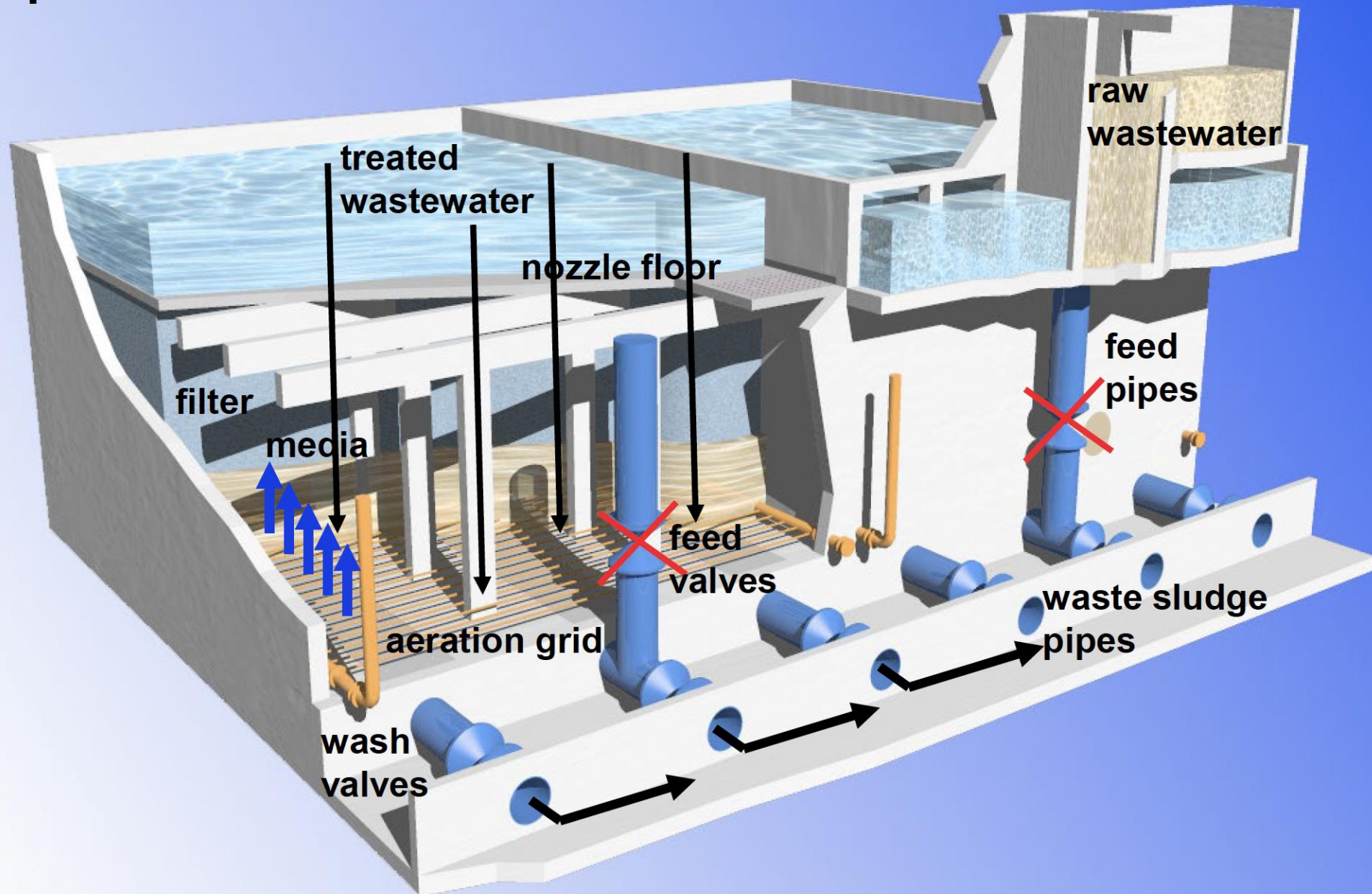
# BIOSTYR

## Operation mode denitrification



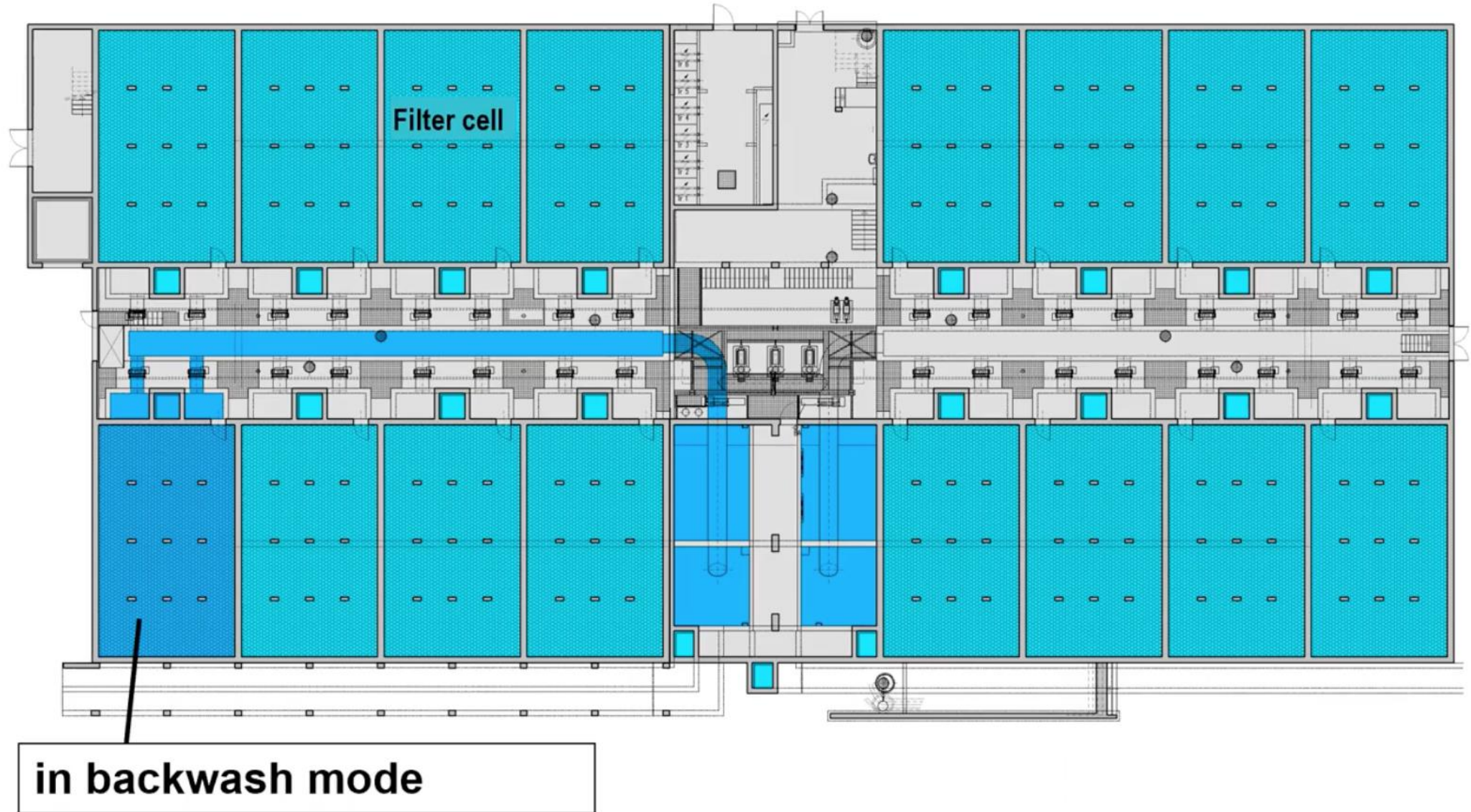
# CONCEPT of Biostyr<sup>®</sup>

## Operation mode Wash



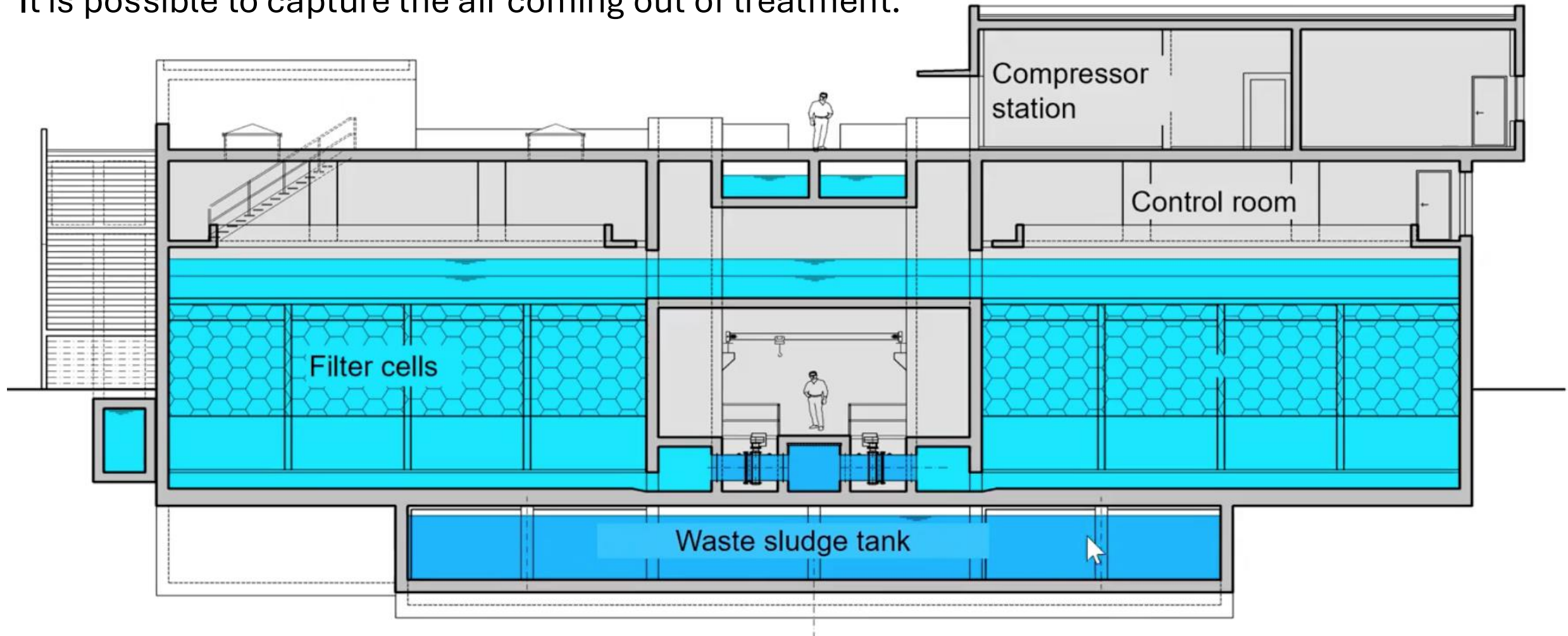
# Biostyr Biofiltration system with 16 cells

ground plan



# Biostyr Biofiltration system with 16 cells cross-section

Things are organized vertically, so area-saving.  
It is possible to capture the air coming out of treatment.



## Some design parameters

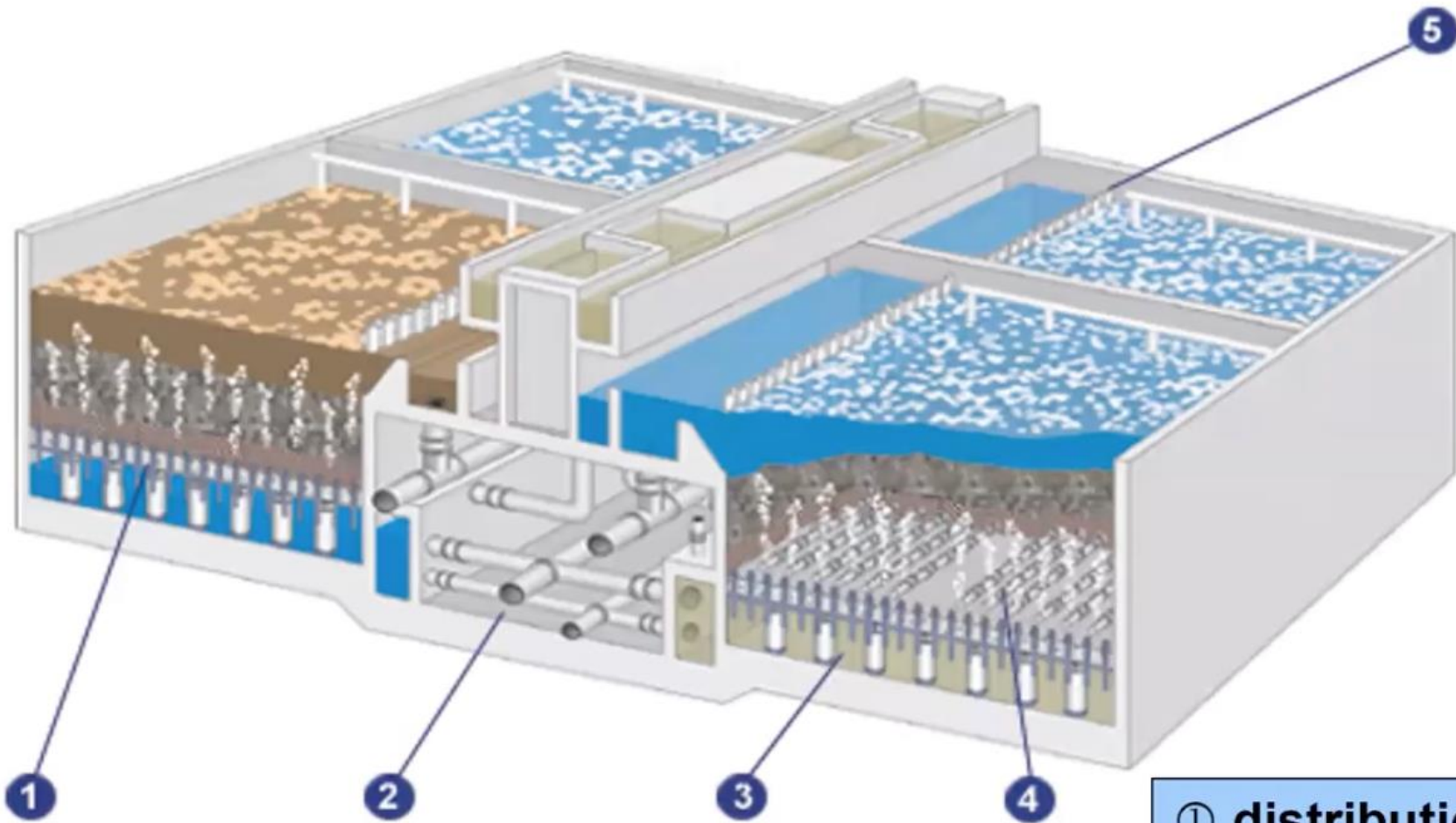
### Filtration rates:

- Carbon 3 - 10 m/h (max. 20 m/h)
- Nitrification 5 - 10 m/h (max. 20 m/h)
- Denitrification ~ 10 m/h (max. 30 m/h)
- Dephosphatation ~ 10 m/h

### Specific loads:

- Carbon 6 - 8 kg<sub>COD</sub>/m<sup>3</sup>.d  
2 - 4 kg<sub>BOD5</sub>/m<sup>3</sup>.d
- Nitrification 0.6 - 1.5 kg<sub>N-NH4</sub>/m<sup>3</sup>.d
- Denitrification 0.6 - 1.0 kg<sub>N-NO3</sub>/m<sup>3</sup>.d for pre-DN  
1.5 - 3.0 kg<sub>N-NO3</sub>/m<sup>3</sup>.d for post-DN
- Dephosphatation 0.4 kg<sub>Ptot</sub>/m<sup>3</sup>.d

**HOMEWORK**



# BIOFOR

- ① distribution nozzles
- ② pipe gallery
- ③ Monoflor underdrain
- ④ Oxazur air diffuser
- ⑤ tranquilizer baffle

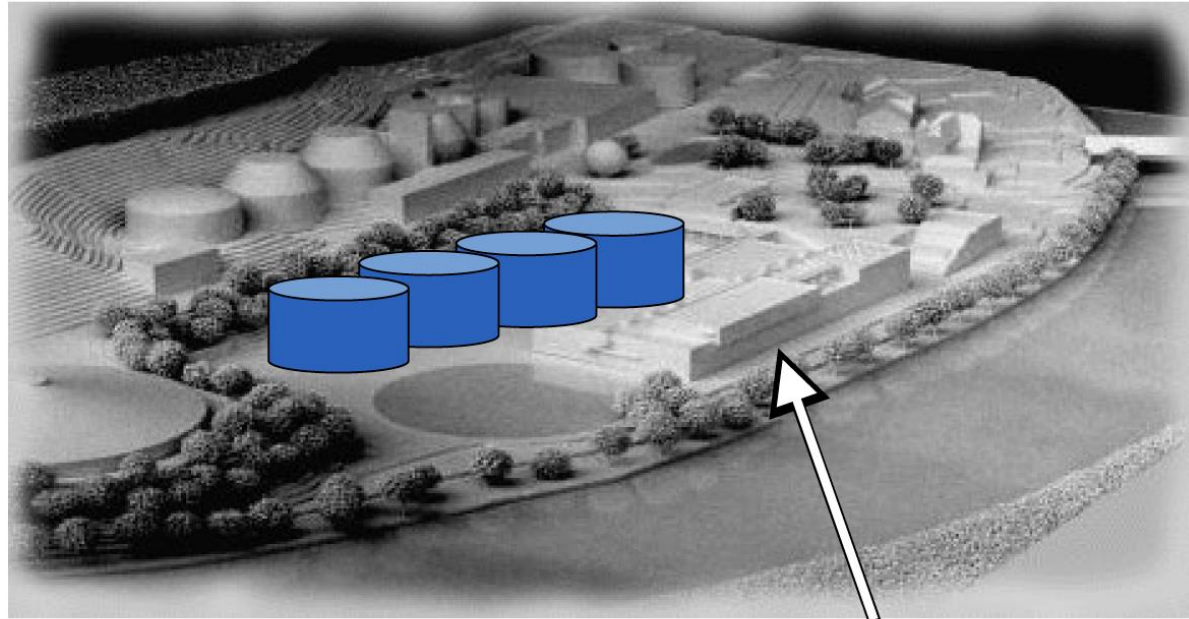
# BIOFOR filter bed material



**Biolite**  
beads of  
expanded clay  
with a diameter  
of 2 to 6 mm

**Heavier than water.  
Do not need cover to keep the beads.**

# Two processes for nitrogen removal (ARA Bern-Neubrücke)



Following information are provided by  
Thomas Haltmeier –  
Biologist (ETHZ)  
Pius Neff – Civil Engineer  
ETHZ/SIA, Project Manager  
/ General Planner

**Treatment of anaerobic digester effluent in an SBR (sequencing batch reactor) system**

**Redesign of biological treatment by replacing trickling filters with « real » biofilters**

# History of this ARA

- In service since 1967
- In place: BOD removal, P precipitation:
  - Primary clarifier
  - Trickling filters / secondary clarifier
  - Sand filtration to treat effluent of secondary clarifier to use the suspended solids to maximum, commissioned in 1985

(Reasoning: trickling filter typically produces poor settleability and higher suspended solids)

- Does not comply with the new discharge requirements (nitrogen)

# History of this ARA

- Sensitive site, release to river Aare, also close to residential area (which was not there in 1960s)

Bern's effluent ultimately enters the Rhine system (North sea), which is under strict international protection (Rhine Protection Convention) on N removal.

Two processes for N removal: biotrickling filters, sludge treatment

**Next lecture:** Effluent of sludge treatment contains high amount of N, high temperature, and low volume.

They modified an old fat removal system to treat digestion effluent separately. As compared to traditionally, bring it back to combine with inflow.

Change on fat removal:

- upstream grease control is better by regulation (e.g., Restaurants now must install grease interceptors).
- primary clarifiers now remove scum more effectively with e.g. skimmer.
- biological processes handle small amounts of FOG

# STEP de Berne / lit bactérien / 2000



# Design goal

- Design Basis
- Population equivalent: 350,000 PE
- Dry weather flow: 1,500 L/s
- Wet weather flow: 3,000 L/s

## Discharge Standards

- TSS                    15 mg/L
- BOD<sub>5</sub>                15 mg/L
- NH<sub>4</sub>-N                2 mg/L
- Total nitrogen (55% removal): 15 mg/L
- P<sub>tot</sub>                    0.3 mg/L

# Mission

- Replacement of the existing biological treatment and improvement of performance (nitrification / denitrification)
- No nuisances (noise, odors)
- Ensure reliable operation during the construction work

## Selected procedure

- **Turnkey contract** (“Entreprise Totale”) →
- **Two-stage procedure**
  - Pre-qualification
  - Submission (tender process)
- **Costs**
  - Capital investment
  - Operating costs over 15 years
- **Qualitative criteria**
  - One company (or consortium) delivers the entire WWTP upgrade or new installation.
  - The client does not coordinate multiple design and construction firms.
  - Performance guarantees (e.g., nitrogen removal, BOD, TSS) are often included.

# Qualitative Criteria

- Evaluation of the proposed processes
- References (experience / past projects)
- Organization
- Quality management
- Environmental performance
- Service offerings
- Land use / scheduling / quality of the proposal

# Requirements and Constraints

- Operation of the wastewater treatment plant during the construction work
- Effluent quality during the construction work
- No nuisances during the construction work
- Contractual conditions and guarantees
- Effluent quality
- Operating costs
- Deadlines / schedule

# Offers

- **Degrémont** part of Veolia (biofiltration)
- **Losinger-Alpha-BG** (biofiltration)
- **Lurgi** (biofiltration)
- **Mannesmann** (Kaldnes)
- **Marazzi** (SBR)
- **VA TECH WABAG** (biofiltration)

# Options

- **Activated sludge** (biological treatment and secondary settling)
  - Two-stage
  - On two levels
- **SBR** (Sequencing Batch Reactor)
- **Fixed-film systems** (biofiltration, Kaldnes)

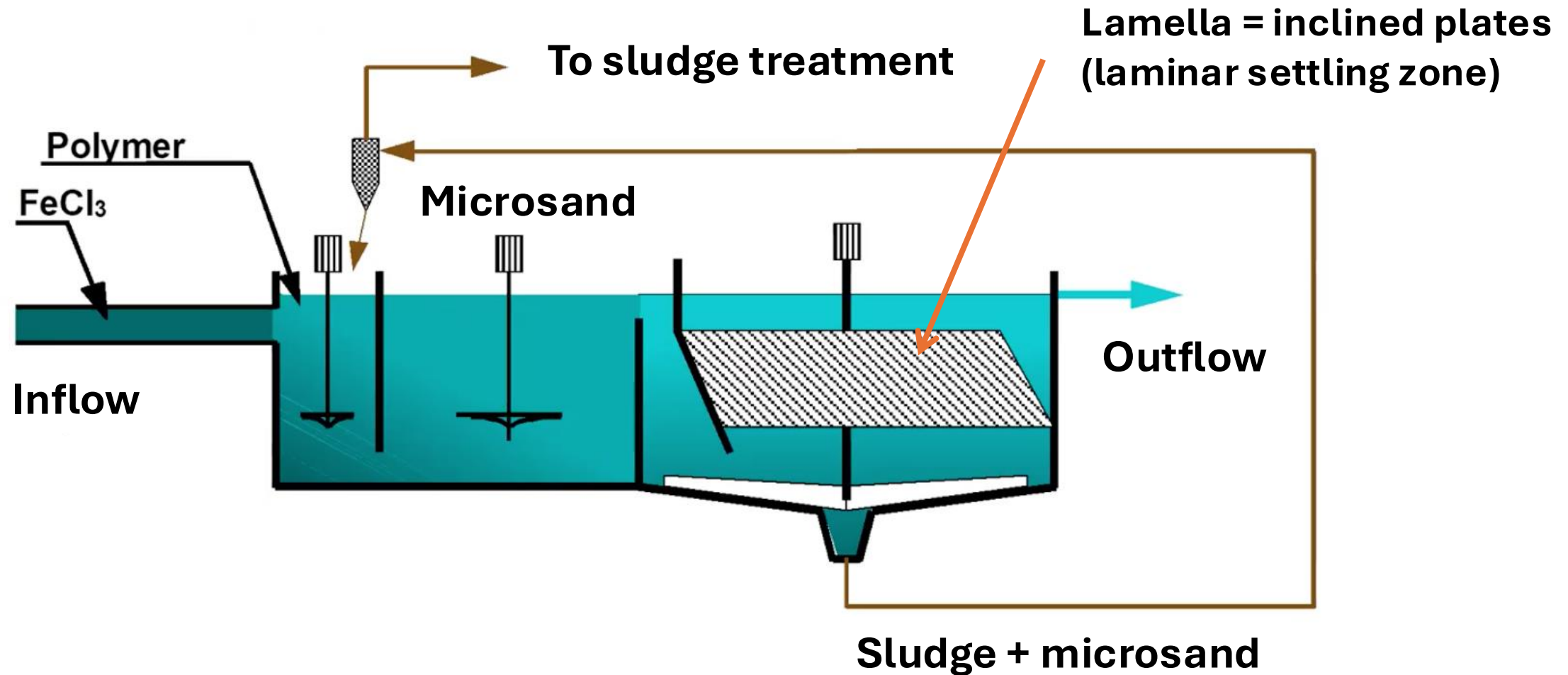
## Chosen option:

**BIOSTYR** (biofilters)

and

**ACTIFLO** (compact settling)

**Actiflo** a ballasted flocculation–settling process used for high-rate clarification.



# Sanitation Concept

- Rehabilitation and optimization of the existing primary settling
- Construction of a new biological treatment stage with biofilters
- Use of the existing filtration after biological treatment
- Treatment of sludge-laden water with an ACTIFLO system

# Why this treatment line and these processes?

- **Very compact structures**
  - Simple construction phasing
  - Low risks during construction
- **Proven and reliable processes**
- **Simple control/operation**
- **Use of ACTIFLO as a secondary clarifier**

# Costs (excluding VAT)

- **Biological treatment** — 64.3 million CHF
  - **BIOSTYR** — 57.8 million CHF
  - **ACTIFLO** — 4.5 million CHF
  - **Primary settling** — 2.0 million CHF
- 
- **Operating costs** — 11 million CHF per year

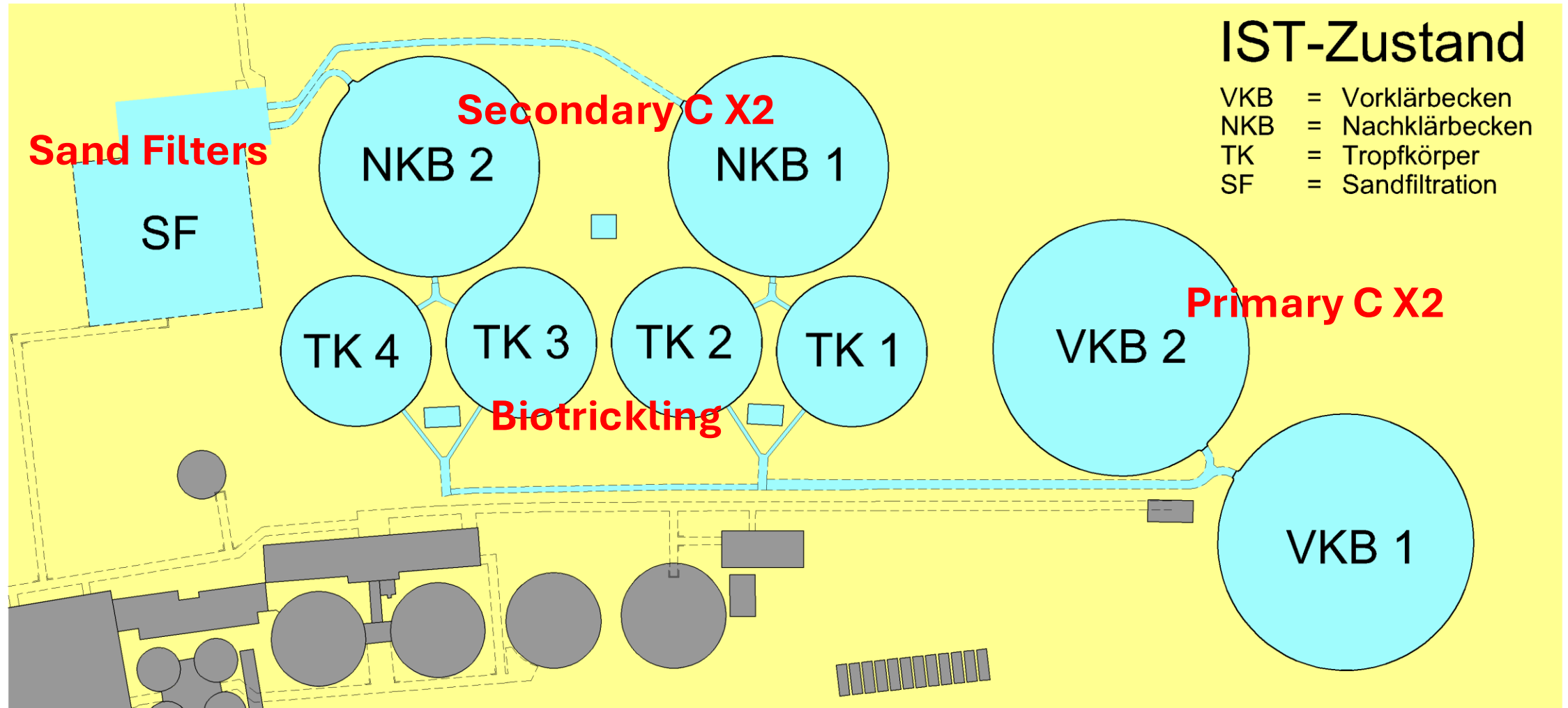
# Risks

- **Failures during the construction works**
  - Damage to existing infrastructure
  - Overloading of wastewater treatment during construction
  - Nuisances (odors / noise)
- **Exceeding discharge standards**
- **Cost overruns** (investment / operation)
- **Failure to meet deadlines**

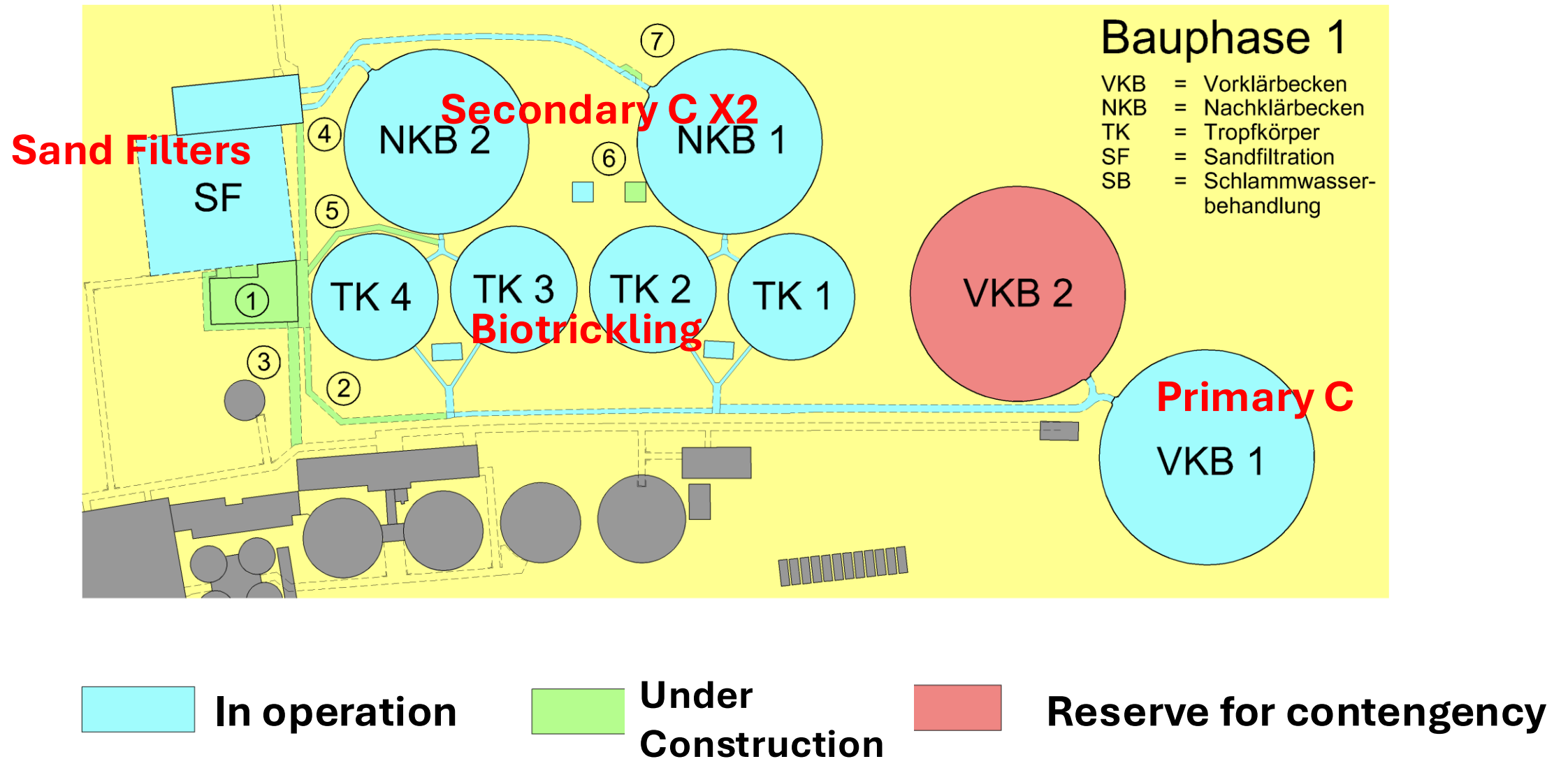
# Schedule

- Publication in the *Amtsblatt* (Official Gazette) of the Canton of Bern — **13.06.1998**
- Submission of the pre-qualification dossier — **23.07.1998**
- Issue of the tender documents — **04.12.1998**
- Visit of the WWTP (mandatory) — **12.01.1999**
- Submission of the offer — **11.06.1999**
- Presentation of the offer — **25.06.1999**
- Contract award — **Dec. 1999**
- Signature of the turnkey contract — **Jan. 2000**

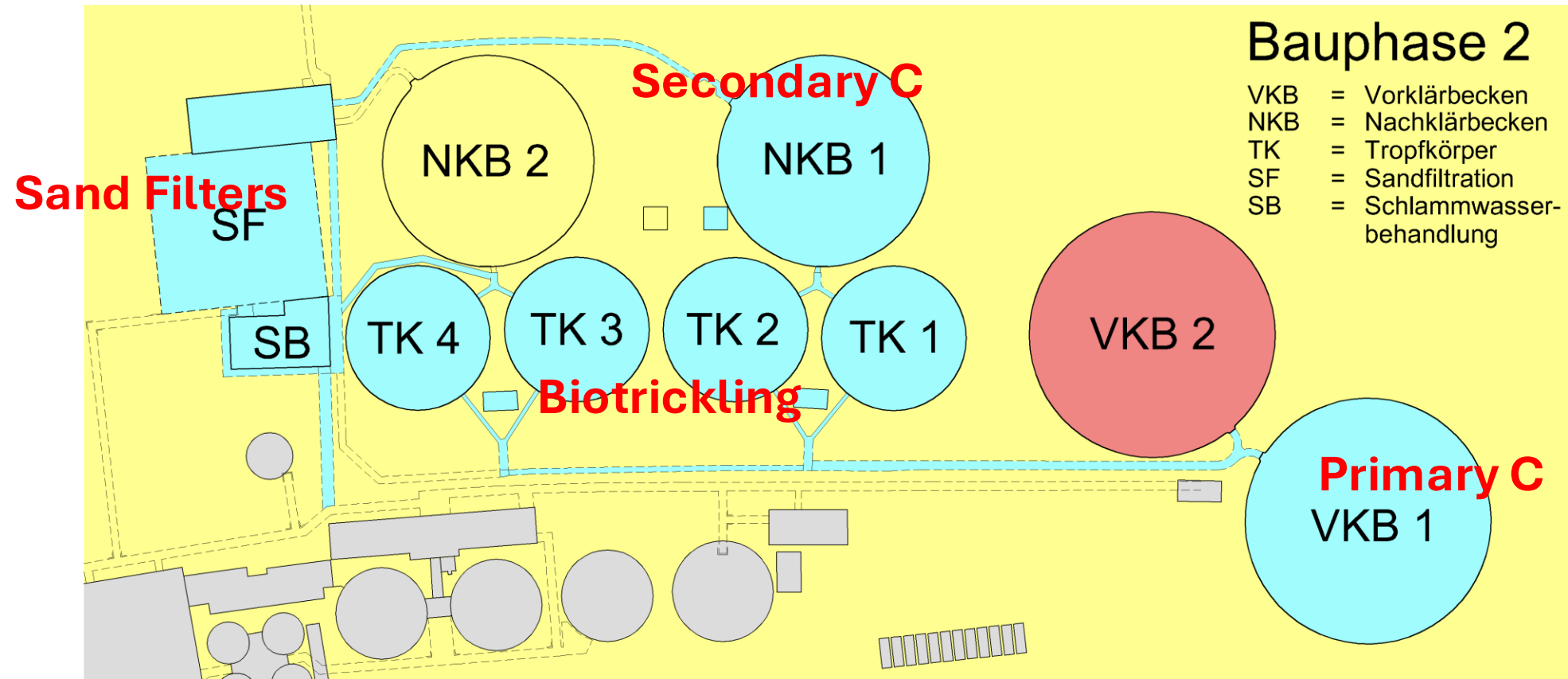
# Situation before redesign



# 1<sup>st</sup> Construction phase



# 2<sup>nd</sup> Construction phase

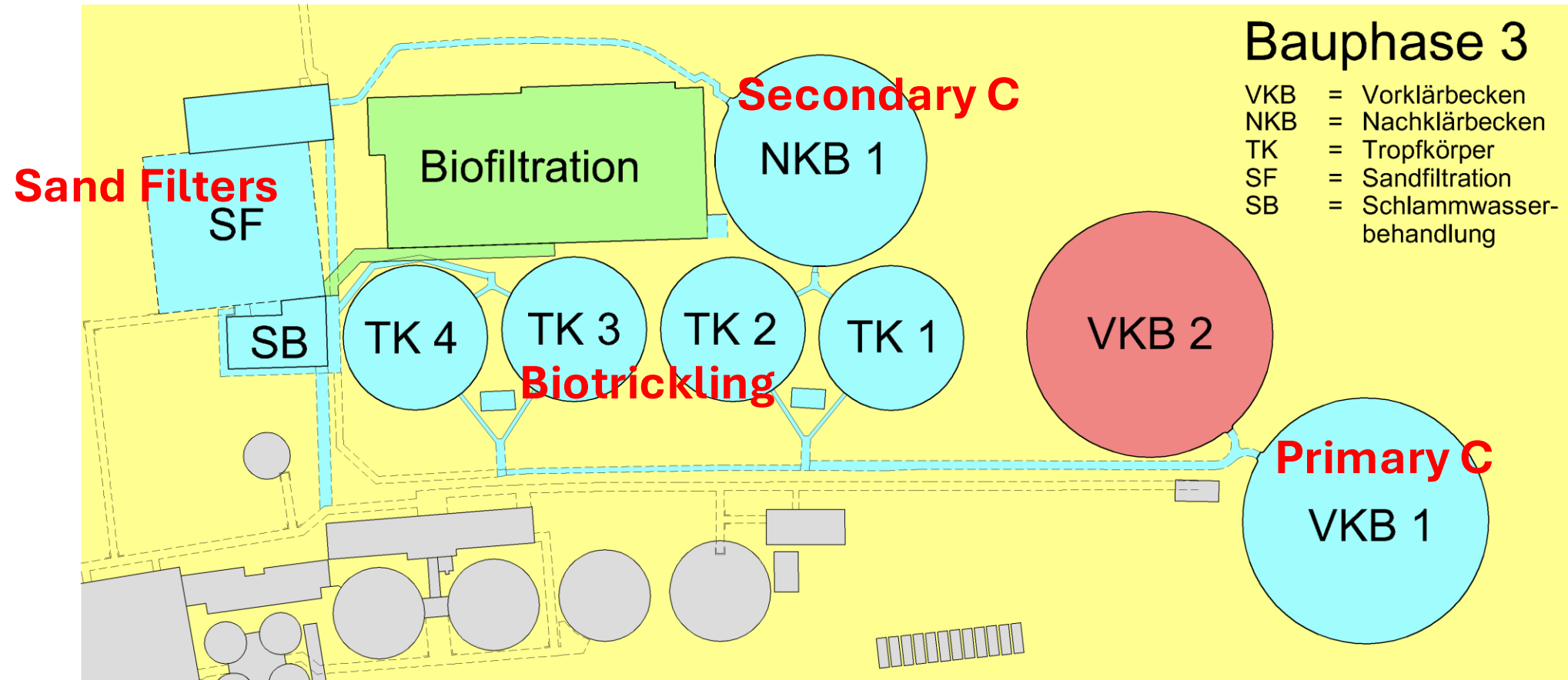


 In operation

 Under Construction

 Reserve for contingency

# 3<sup>rd</sup> Construction phase



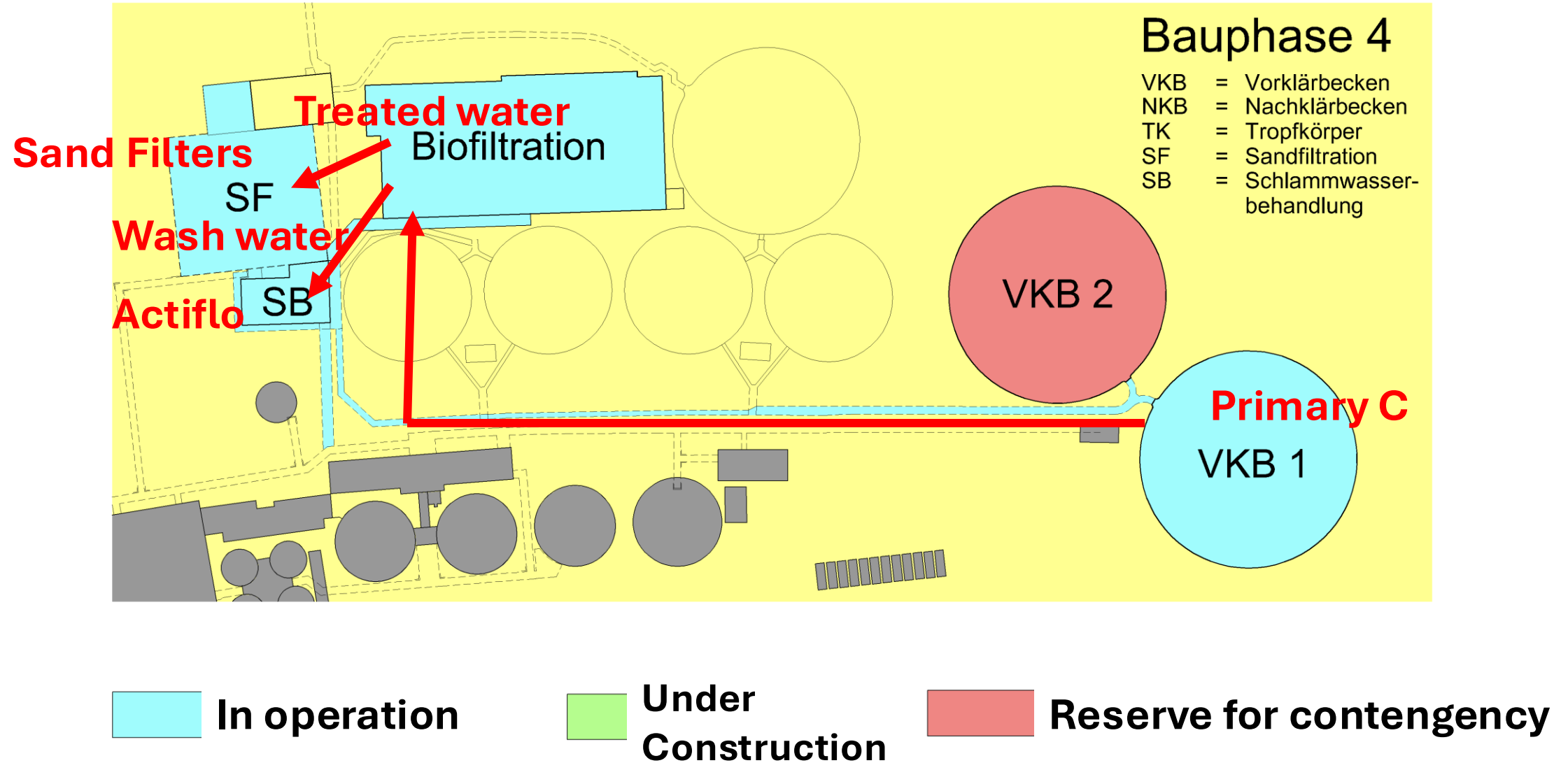
**In operation**      **Under Construction**      **Reserve for contingency**

# Sizing

- **16 BIOSTYR cells with 113 m<sup>2</sup> surface area each at 400 m<sup>3</sup> volume → 6,400 m<sup>3</sup> total**
- **Compact building: 40 m × 80 m**
- **Active biological surface area**
  - Specific surface area: **1,200 m<sup>2</sup>/m<sup>3</sup>**
  - Total surface area: **7,680,000 m<sup>2</sup>**  
→ **equivalent to 1,075 football fields**

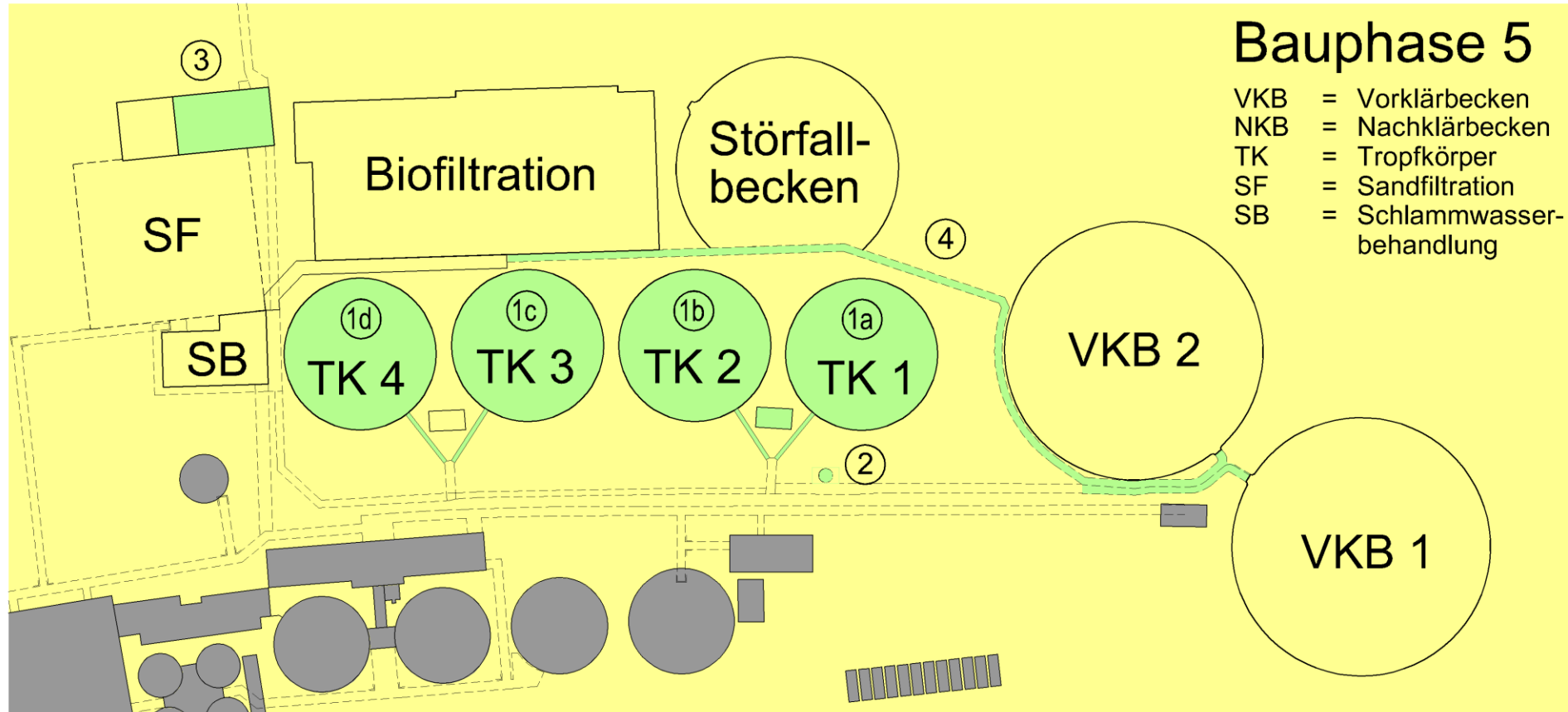
# 4<sup>th</sup> Construction phase

Water → primary C → Bilfilter  
→ wash water then goes to  
actiflo, and treated water  
goes to sand filters → River



# 5<sup>th</sup> Construction phase

Deconstruct biotricking filters



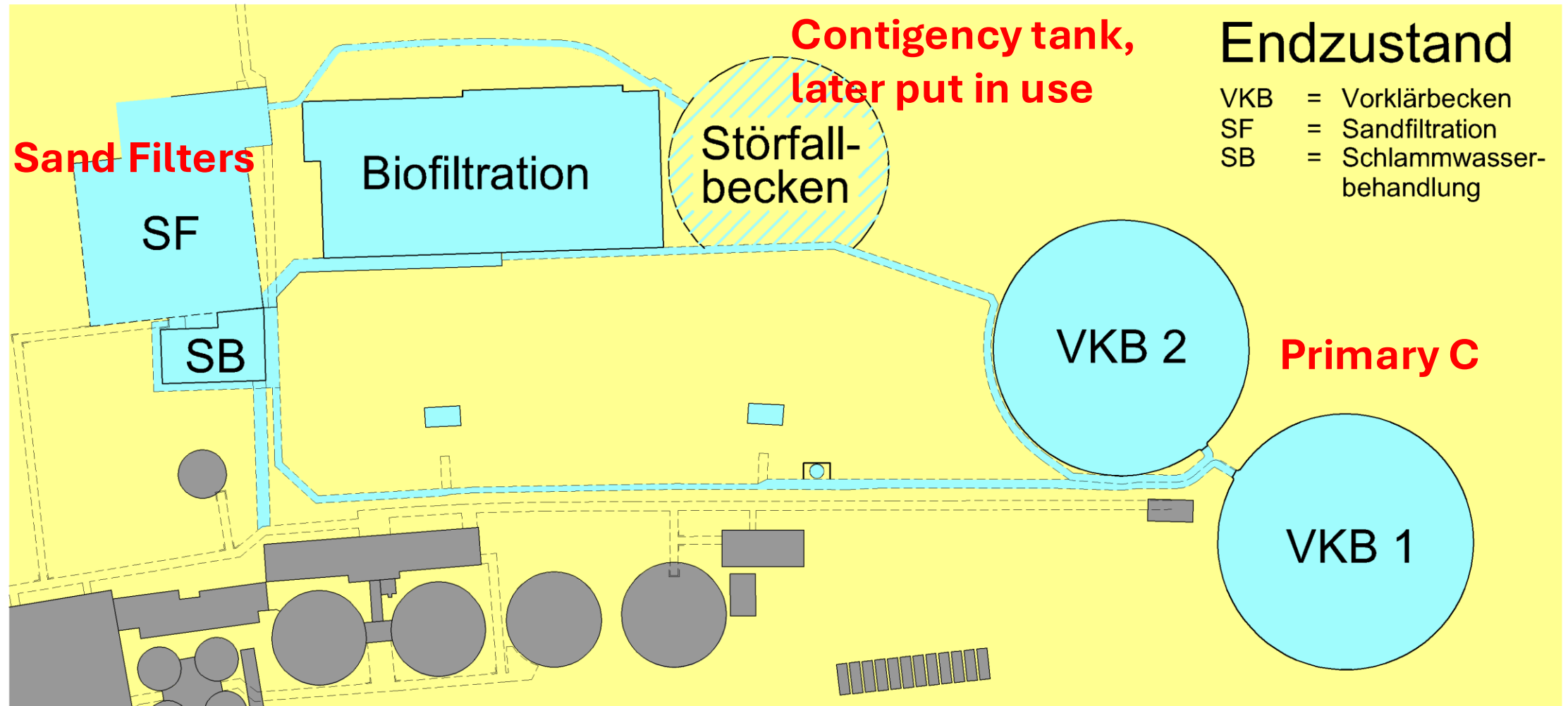
 In operation

 Under Construction

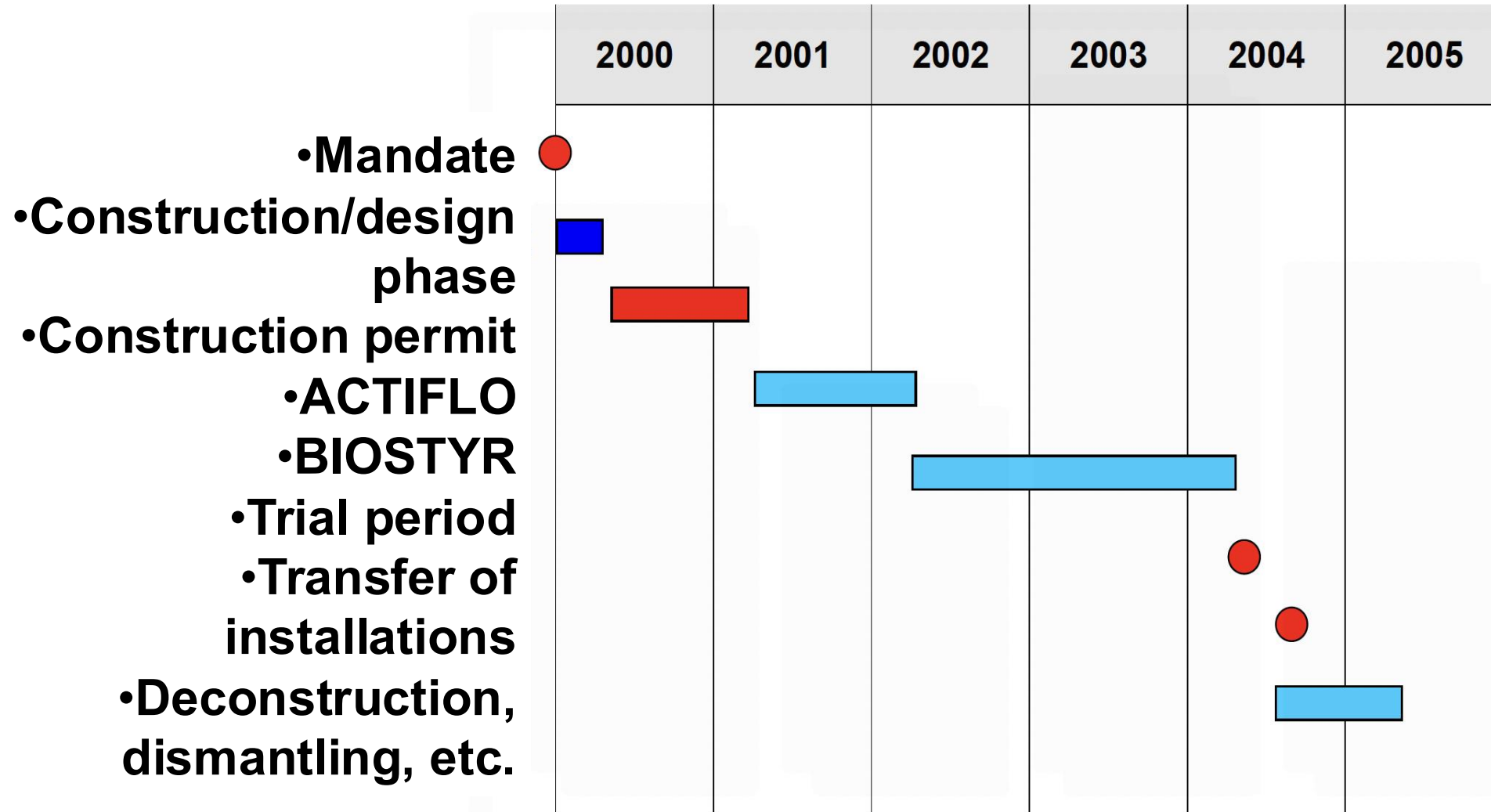
 Reserve for contingency

Water goes from both sides after PC into biofiltration.

# Situation after redesign



# Planning



# STEP de Berne / Biofiltration



# WWTP Bern 2015

## New developments



Biofilters for  
air treatment

Digestion  
effluent N  
treatment

Sludge drying  
facility