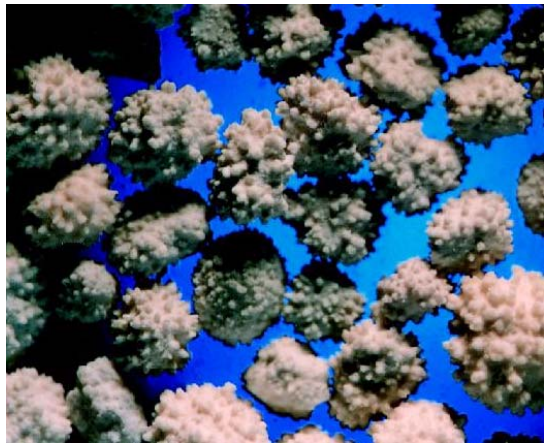
P-recovery with THE CRYSTALACTOR®

…efficient water treatment without waste



Andreas Giesen, DHV, Andreas.Giesen@DHV.com

DHV

Consultancy and Engineering

Consultancy and Engineering

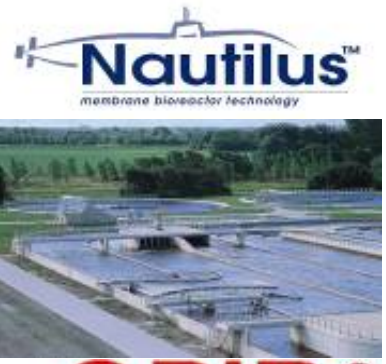
- 5000+ staff
- Markets
  - Transportation
  - Building and Manufacturing
  - Water
  - Aviation
  - Metal & Mining
  - Spatial Planning and Environment
- Services
  - Management consultancy and advisory services
  - Design and engineering
  - Project and contract management
  - Operations management
  - Total solutions

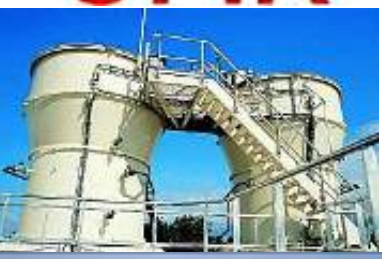
Consultancy and Engineering

Sustainable solutions for water

Gateway to solutions

Our motor to success: Innovation and R&D





To stay at the head of the market and offer the best possible optimizations and sustainable solutions to our Clients, innovation and R&D is an essential arm of the Company

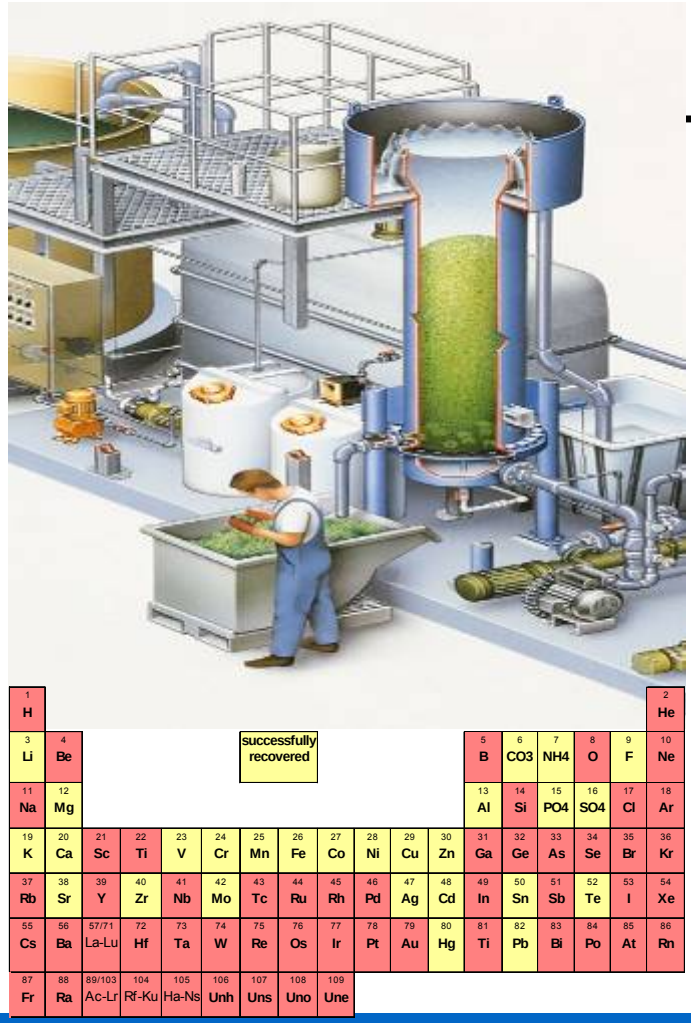
Consultancy Engineering Company with largest R&D expenditure and most patents in Benelux and top in Europe

Development of world famous water technology and concepts

Carrousel®, B.A.B.E.®, Nereda®, Airflush™, OptiFlux™, Nautilus™ MBR, Crystalactor®, Crest-Drainage Dike, BioWatch, ABR™, OPIR®, OAS™, DWARS-filter, Carcon™, MBTF, Simba, Rainbow™, Octopus™, Deltadryer, WaterScan, Oxyrator®, Oxycap™, AirWave,…….

The Crystalactor

…. Development timeline



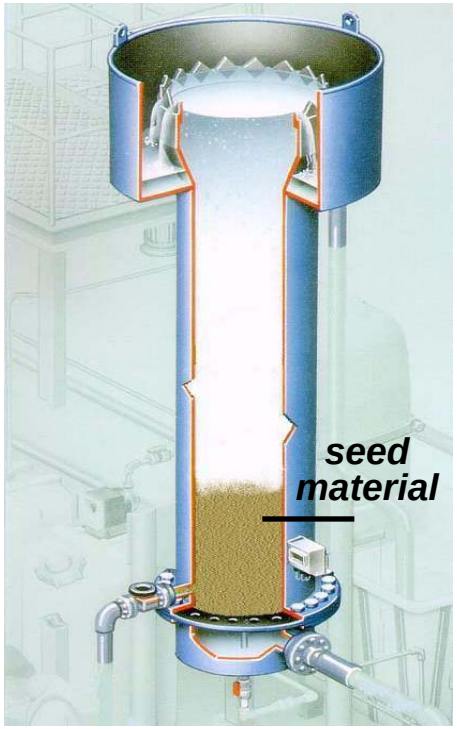
1980 • softening of process and drinking water

1985 • metal recovery from process and wastewater

1985 • phosphate recovery from wastewater

1990 • fluoride recovery from process and wastewater

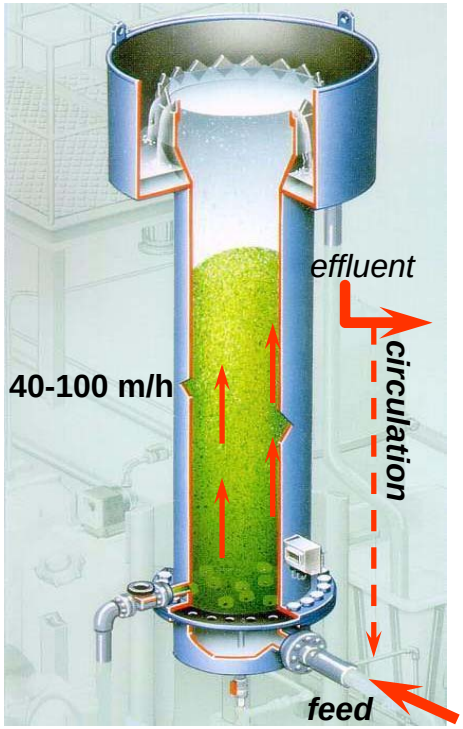
2005 • water recovery membrane concentrates



Crystalactor®

- crystallization in pellet reactor

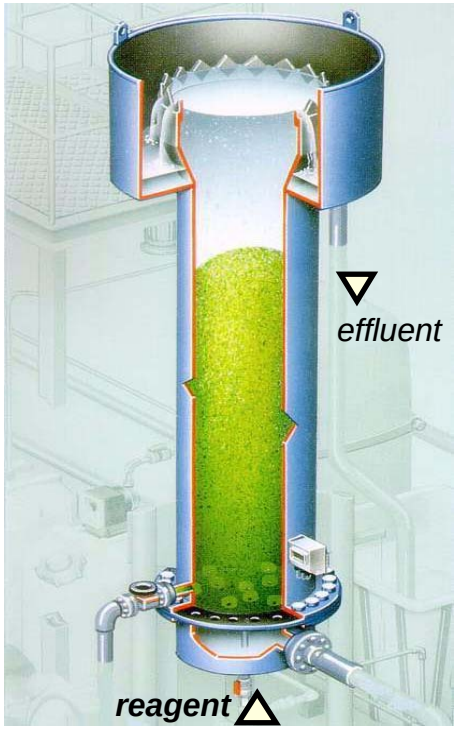
- applications
  - ◊ softening
  - ◊ phosphate recovery
  - ◊ heavy metals recovery
  - ◊ fluoride recovery
  - ◊ pre-treatment for de-ionisation
  - ◊ pre-treatment for inland desalination
  - ◊ water recovery from membrane concentrates



Crystalactor®

- crystallization in pellet reactor

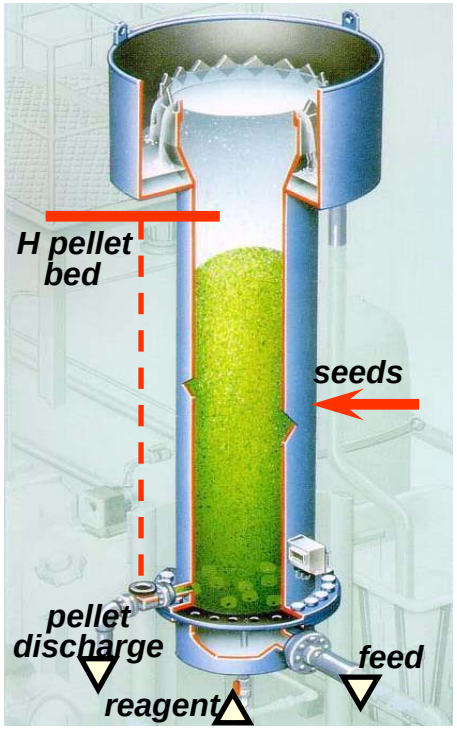
- applications
  - ◊ softening
  - ◊ phosphate recovery
  - ◊ heavy metals recovery
  - ◊ fluoride recovery
  - ◊ pre-treatment for de-ionisation
  - ◊ pre-treatment for inland desalination
  - ◊ water recovery from membrane concentrates



Crystalactor®

- crystallization in pellet reactor

- applications
  - ◊ softening
  - ◊ phosphate recovery
  - ◊ heavy metals recovery
  - ◊ fluoride recovery
  - ◊ pre-treatment for de-ionisation
  - ◊ pre-treatment for inland desalination
  - ◊ water recovery from membrane concentrates



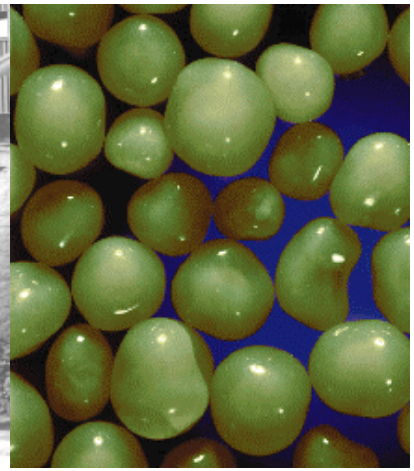
Crystalactor®

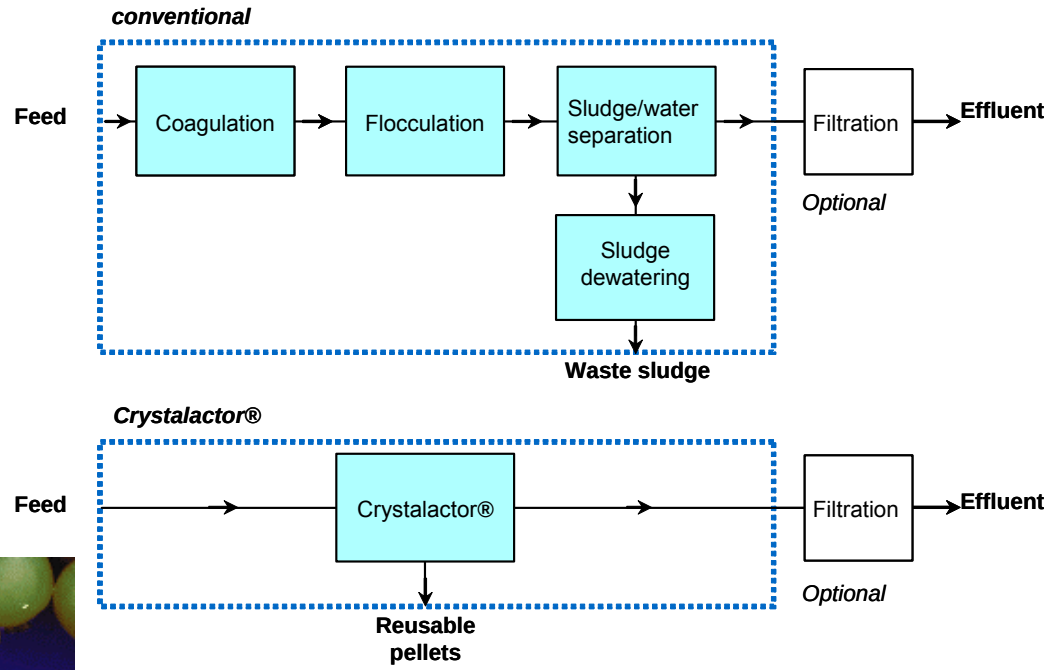
- crystallization in pellet reactor

- applications
  - ◊ softening
  - ◊ phosphate recovery
  - ◊ heavy metals recovery
  - ◊ fluoride recovery
  - ◊ pre-treatment for de-ionisation
  - ◊ pre-treatment for inland desalination
  - ◊ water recovery from membrane concentrates

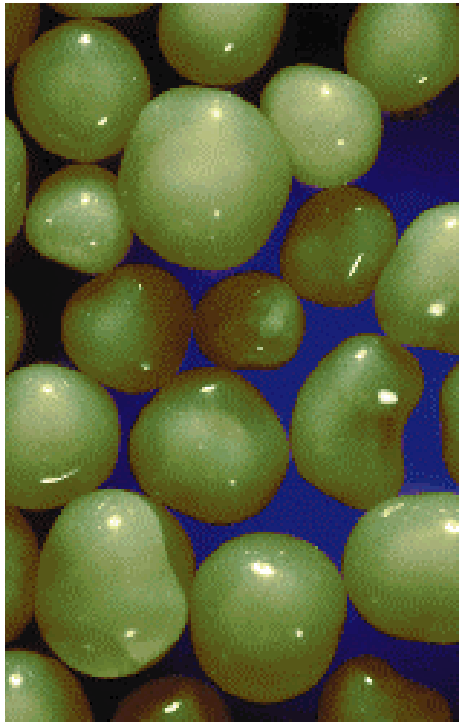
Advantages

- **compact**
  - four steps in one





- zero or minimum waste



Pellets

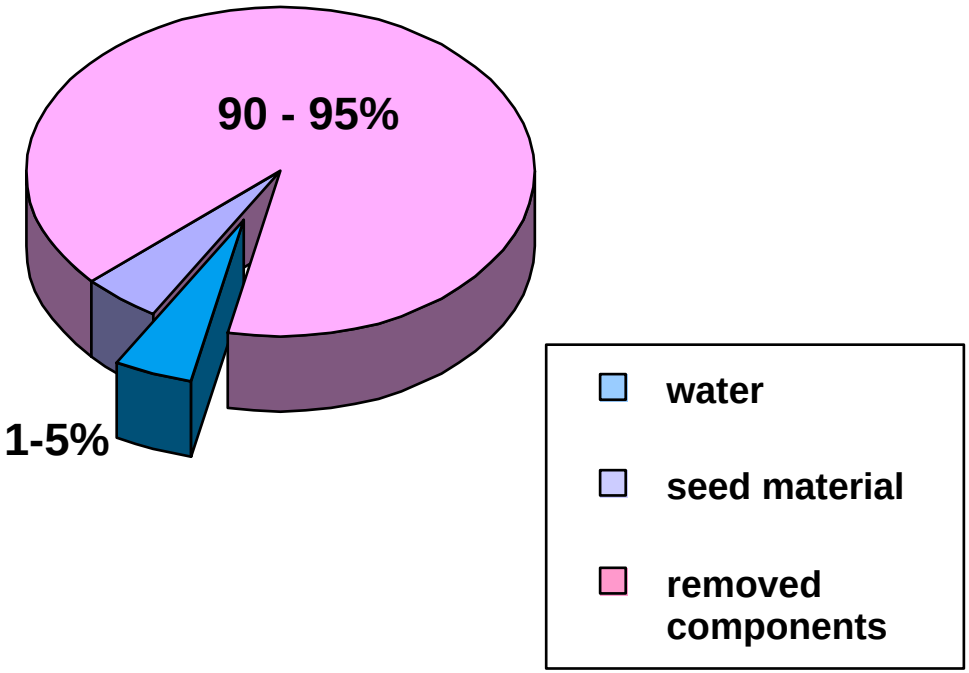
- Very compact pellets are produced
- Easy handling
- Low water content (<5%)
- High purity
- Reusable
- Often: Negative or zero disposal costs

Composition by-products

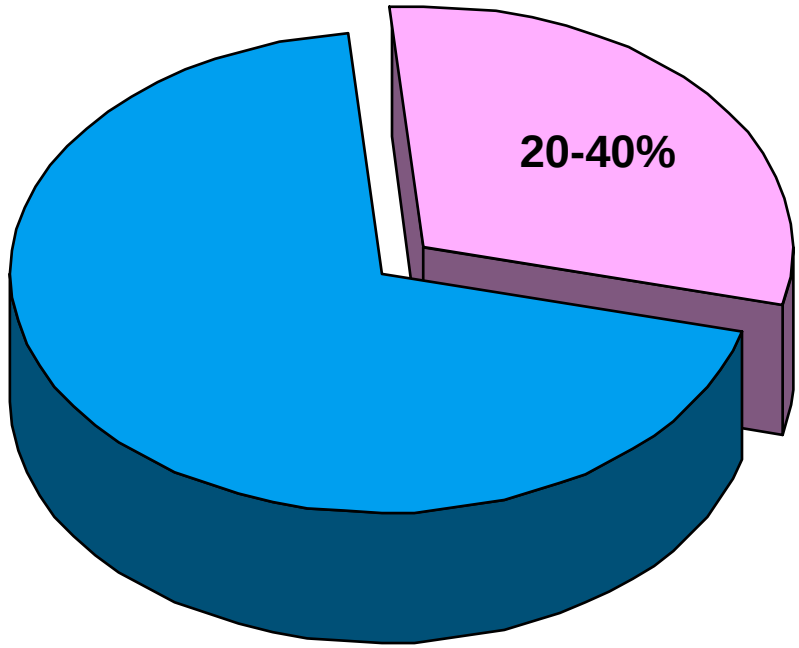
Consultancy and Engineering

DHV

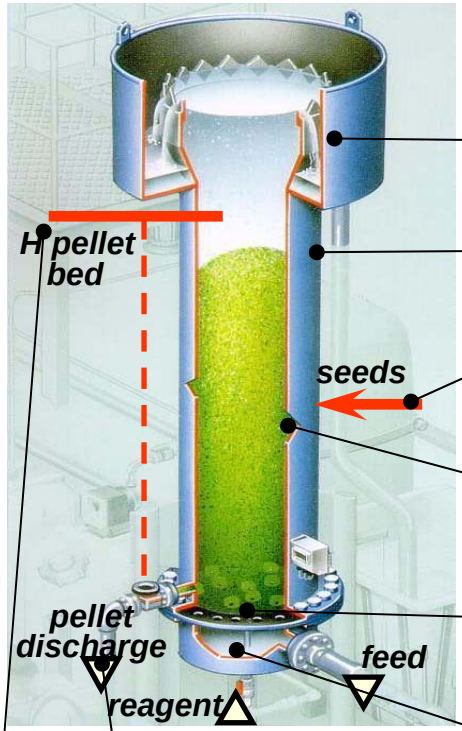
Crystalactor®



Conventional precipitation



Crystallizer characteristics



Flexible design → *circular, rectangular, steel, concrete, plastic*

High upflow velocity → *compact, cost-effective design*

Seeds → *easy start-up; stable fluidized-bed; large crystallization area*

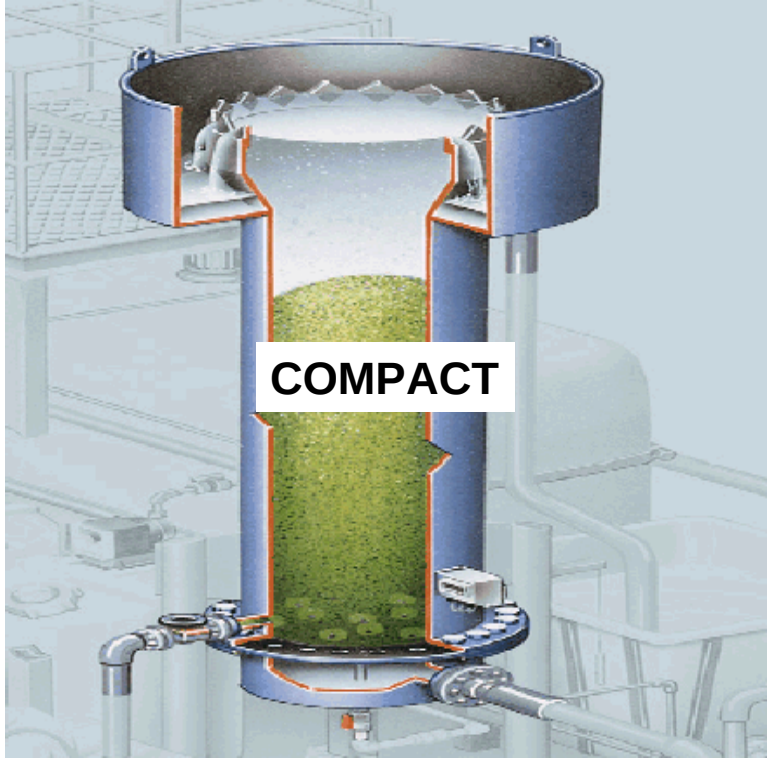
Controlled process conditions → *fast kinetic; maximize crystal growth*

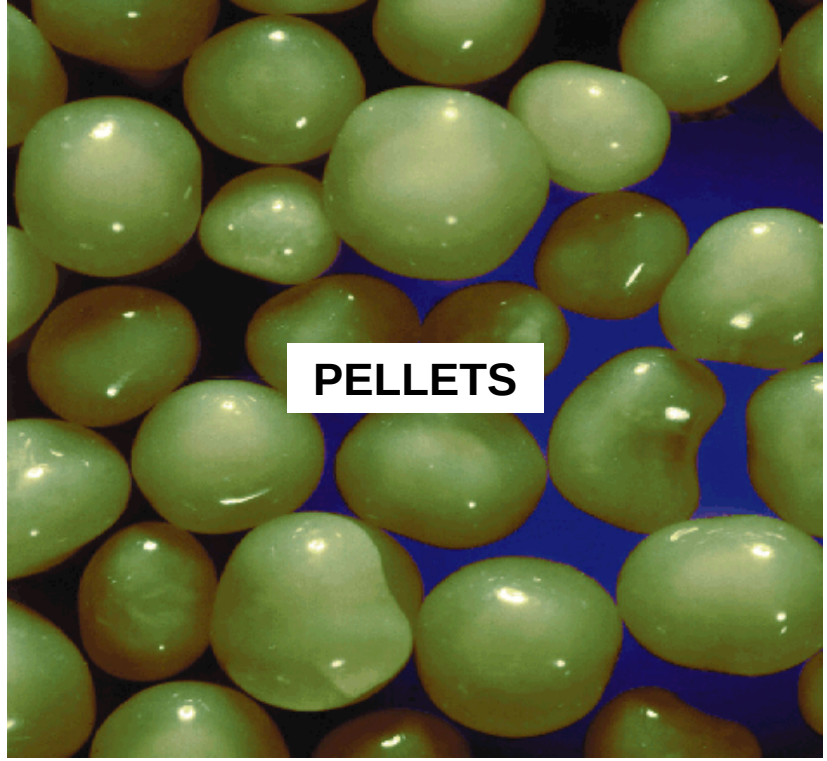
Advanced mixing → *maximize crystal growth; prevent disintegration of crystals, minimal SS in effluent*

Retractable reagent devices → *on-stream maintenance*

1 mm pellet → *free flowing; easy dewatering & drying; easy handling; many reuse applications*

full automation of pellet bed control → *minimal operator attention; reliable operation*


COMPACT


PELLETS


ZERO / MINIMAL WASTE


ENVIRONMENTAL SOUND

Fong Shan Water Supply

- Capacity 350,000 m^3/day domestic water supply plus 450,000 m^3/day industrial water supply

- Flow scheme includes 6 concrete Crystalactor's

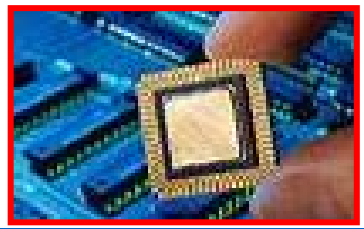
- Services (for whole flow scheme):
  - Design & commissioning
  - Detailed design & construction supervision & supply & delivery of key equipment
  - 15 years Operation & Maintenance

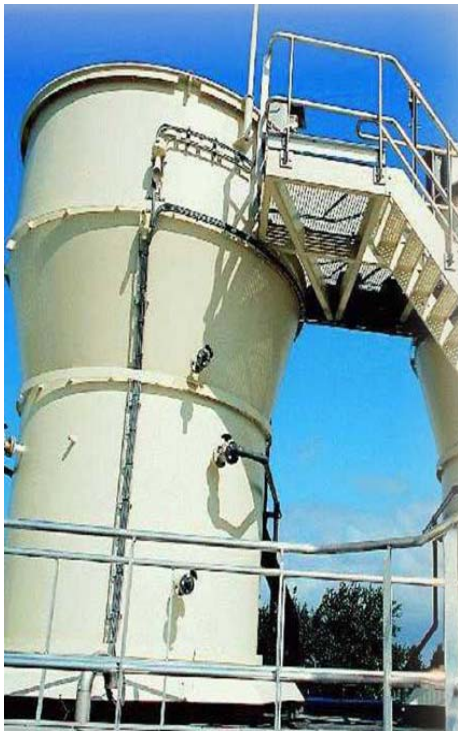
Shell Berre – Kraton Polymers

- Recovery of catalysts from polymer production
- Simultaneous Ni and Al
- Process integrated
- Turn-key project

Ricoh - Japan

- Constructed by licensee Organo Corp.
- Pellet Reactor 1,000 mm
- 1,000 ppm F → < 15 ppm
- 100 ppm P → < 10 ppm
- In operation since: April 2001
- Pellets recycled to HF-supplier
- Awarded as best environmental technology!





Phosphate recovery

- Applications
  - process streams or end-of-pipe
  - in combination with anaerobic biotreater
  - in combination with aerobic biotreater
    - ◊ end-of-pipe
    - ◊ in side stream with biological phosphate concentration

- Production of

$Ca_3(PO_4)_2$ $Mg_3(PO_4)_2$

$MgNH_4PO_4$ $Zn_3(PO_4)_2$

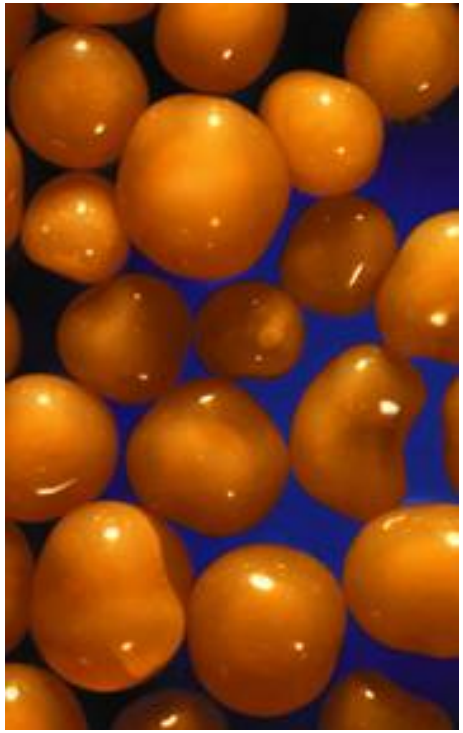
Phosphate recovery reactions

$2\ PO_4^{3-} + 3\ Ca^{2+} \rightarrow Ca_3(PO_4)_2$

$PO_4^{3-} + Mg^{2+} + NH_4^{+} \rightarrow MgNH_4PO_4$

$2\ PO_4^{3-} + 3\ Mg^{2+} \rightarrow Mg_3(PO_4)_2$

$2\ PO_4^{3-} + 3\ Zn^{2+} \rightarrow Zn_3(PO_4)_2$



Re-use example phosphate pellets

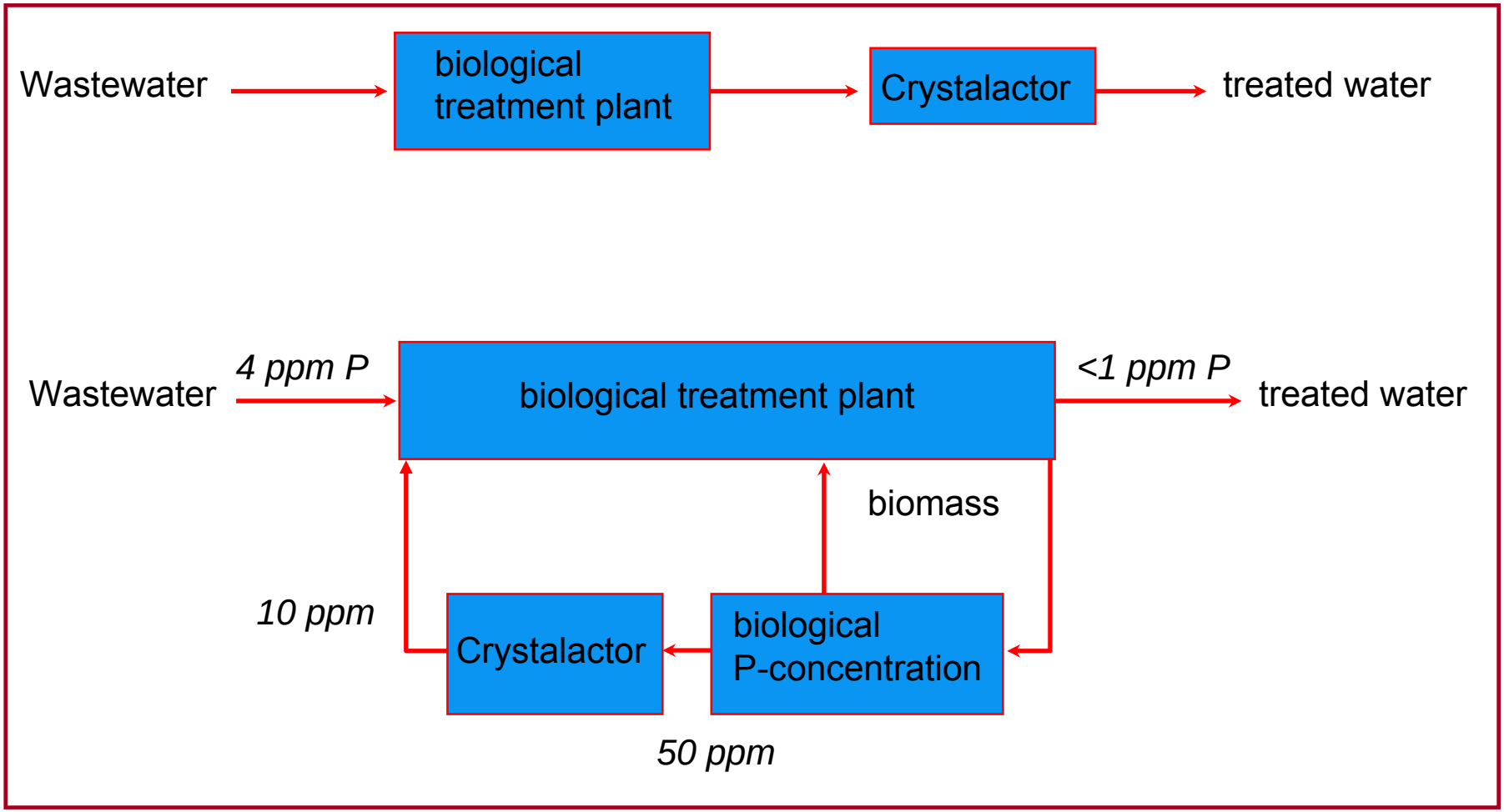
- sell as fertilizer
- sell to agro-industry
- thermal phosphorus production
- wet phosphate production

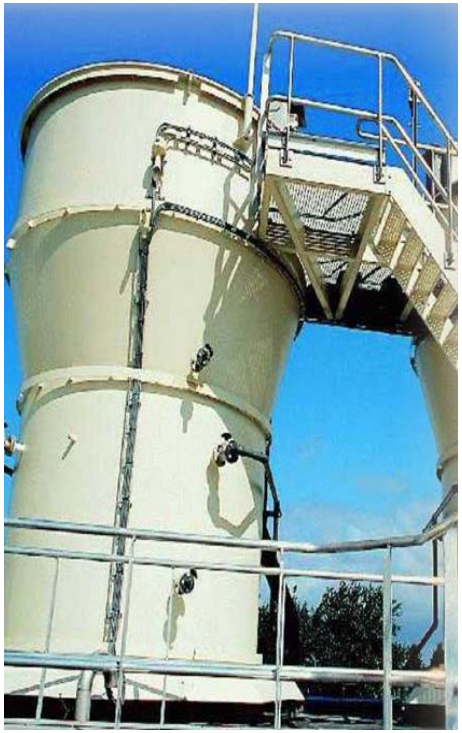
Westerbork

- Phosphate removal
- Municipal Wastewater Treatment
- Capacity: 12,000 p.e.
- <1 mg/l P effluent
- Pellets sold to phosphate processing industry

Crystalactor and biological WWTP

Consultancy and Engineering





Geestmerambacht

- Phosphate recovery from Municipal Wastewater Treatment Plant in combination with biological phosphate concentration (1991)
- Capacity: 262,000 p.e. (max. flow 250 m3/h)
- $Ca_3(PO4)_2$ route
- Design: 60-80 $\rightarrow$ 15-20 ppm (no filtration)
- Pellets reused by phosphate processing industry

Side-stream P-recovery unit

1. P-stripper (anaerobic)
2. decanter/thickener
3. cascade
4. Crystalactor®
5. sand storage
6. lime storage
7. selector

Approx. 1 million kg phosphate recovered

Pilot plant potato starch

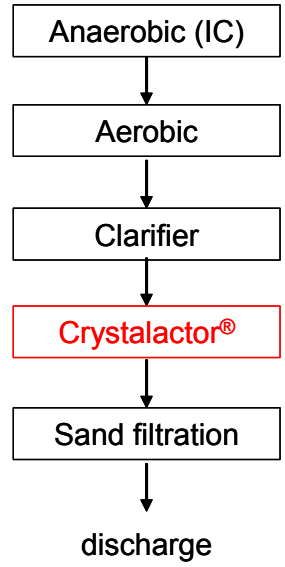
- $MgNH_4PO_4$- crystallization
- Scaling prevention
- 120 mg/l P in feed (150 m3/h)
- Effluent 3-30 mg P/l (no filtration)
- Co-removal N results in lower levies
- Pellets are slow release fertilizer and can be directly used as intermediate in granulation

Phosphate recovery USA

- Dairy industry, Wisconsin (USA)
- Effluent aerobic biotreater
- One reactor (Ø 3.0 m)
- Capacity: 125 m^3/h with 25 ppm P
- Lime used as reagent
- Effluent quality < 2 ppm P
- Built by US licensee Procorp Enterprises LLC
- Technology embraced by Wisconsin Department of Natural Resources

AIPM Hadera, Israel

- Paper mill effluent
- Twofold aim:
  1. Compliance with P-requirement < 1 mg P/l
  2. Reduction of hardness and alkalinity for water reuse
- Reactor: Ø 2.5 m, 9 m high
- Flow: 350-500 m^3/h
- [Ca-in]: 225-275 mg/l, [PO_4-P-in]: 1-3 mg/l
- Effluent: [Ca] < 30 mg/l, [PO_4-P] < 0.3 mg P/l
- Alkalinity-reduction (10 mmol HCO_3^-/l)
- Conductivity / TDS reduction
- Partial reuse of effluent in paper industry
- First Crystalactor for wastewater softening!
- Project partner: EPT Israel



DNCC (DSM) Nanjing, China

- P-removal via struvite crystallization
- Max flow 200 m^3/h
- Diameter Crystalactor= 2.75 m
- P from max. 180 → < 10 ppm P
- Use of specific waste streams as reagent
- Start-up date October 2009

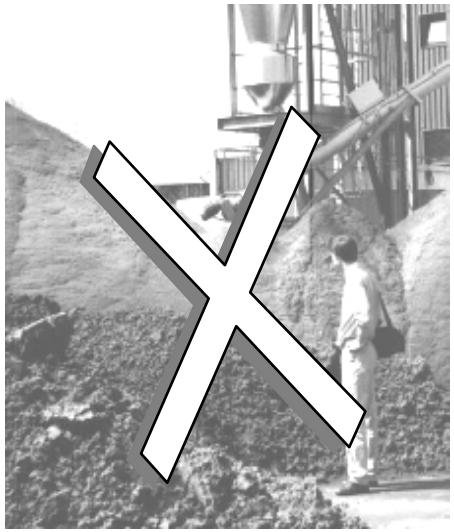
Madison Metropolitan Sewerage District

Filtrate only	
Flow	0.216 MGD
TP	174 mg/L
Ca	40 mg/L
NH4	980 mg/L
Mg	15 mg/L

Filtrate + WAS P Release	
Flow	1.18 MGD
TP	126 mg/L
Ca	70 mg/L
NH4	180 mg/L
Mg	50 mg/L

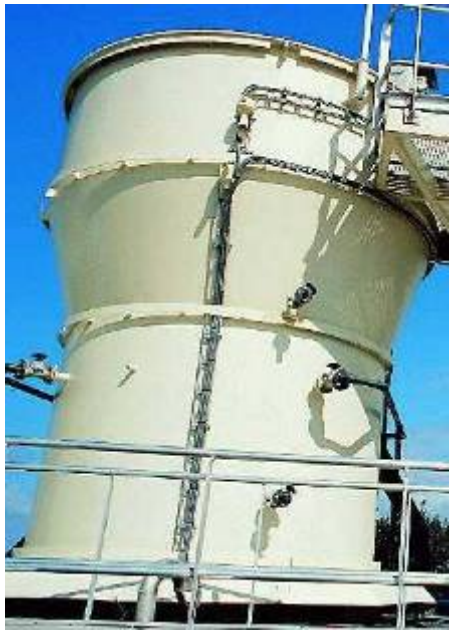
- Test struvite recovery on two streams Procorp Enterprises LLC
  - Digesters Gravity Belt Thickener filtrate
  - GBT filtrate and simulated WAS P release
- No relevant effect of high suspended solids level
- Performance comparable with Ostara previous pilot results at same site. Factor 4 smaller crystallizer volume.

Crystallization and P-recovery



- Crystalactor is an improved precipitator
- Many P-recovery routes apply a precipitation step (RIM-NUT; PHOSTRIP; Aqua Reci; CAMBI; PRISA, etc.)
- Available to cooperate/support synergetic integrations
- struvite crystallization is often most economic route if ammonium is available
- A hot new source: urine and manure

Conclusion



- Crystalactor technology is attractive alternative to precipitation
- Proven P-recovery with zero waste
- Extensive experiences available
- Crystalactor can be an important tool in various process and flow schemes for realising a sustainable phosphate upcycling

P-recovery with THE CRYSTALACTOR®

…efficient water treatment without waste