

"The projects have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreements No 723577"

Innovative water treatment and use of alternative water resources in iron and steel industry

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Situation - Solutions - Aims

Water – high quantities but limited useable and up coming future challenges

Total Water Reserves

- 97,5% Salt water
- 2,5 % Fresh water

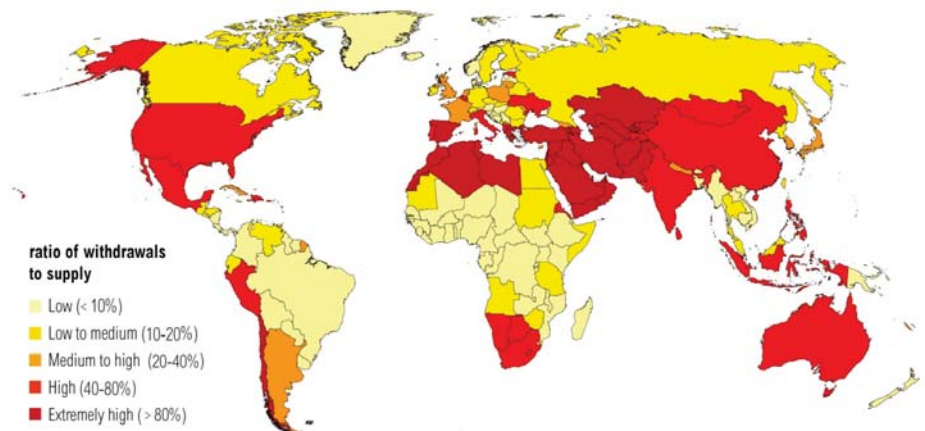
Freshwater

- 70% Glacial ice
- 30% Soil
- 0,7% Readily available for human use

Water scarcity – an up coming issue for the future

- Not limited to aride /semi-aride regions
- Need to decoupling of production form water consumption

Water Stress by Country: 2040



NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.

For more: ow.ly/RiWop

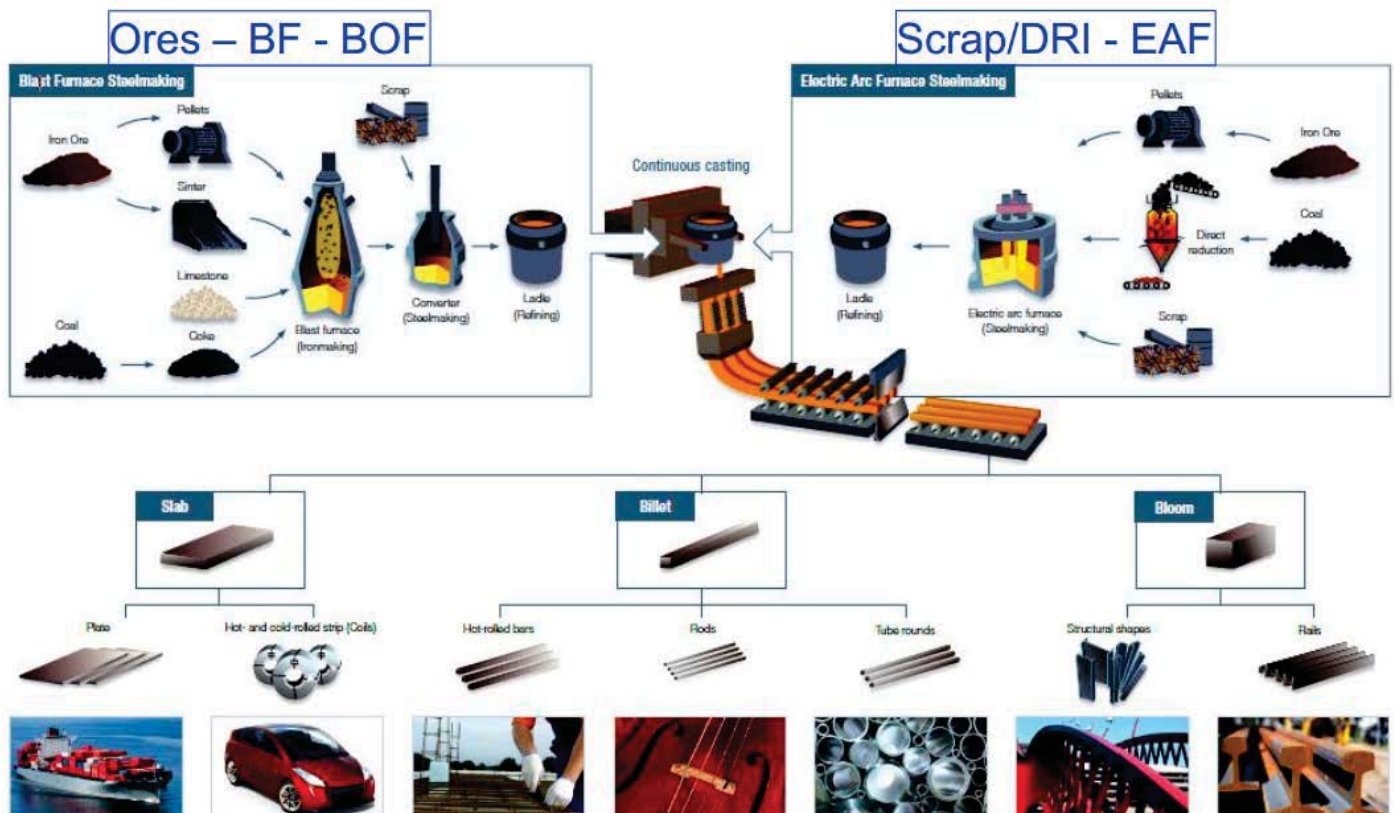
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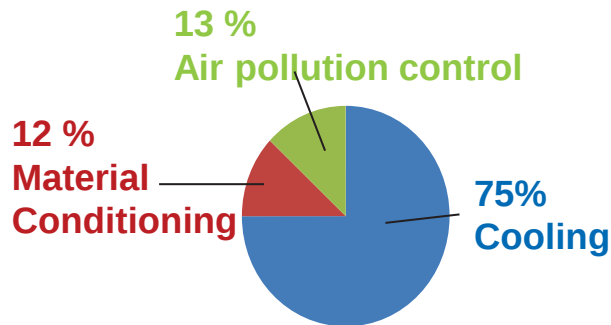
Steelmaking production routes From raw material to product



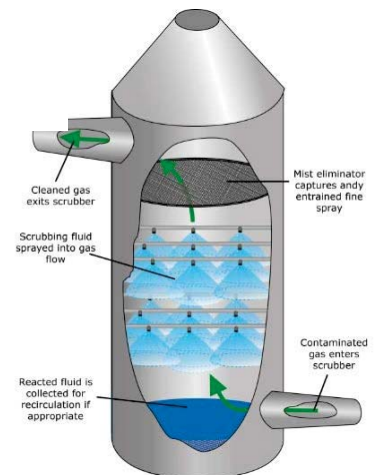
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- Cooling applications: material: casting, hot rolling, machines, oven
- Air pollution control: gas washing e.g. blast furnace, basic oxygen furnace
- Material conditioning: e.g. slag granulation
- Water sources: Ground water, river water
- Alternative water sources: sea water, back washing water sand filter, cooling water from indirect/direct cooling discharged, gas washing water discharged



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Situation - Challenge - Solution

Situation

- **Process related intake** of solids (Fe, carbon) and organic (oil/grease) causing wear and enhancing biological activity
- Concentration of **salts/hardness** components leading to **corrosion and scaling**
- **Addition** of corrosion inhibitors, antiscalants and biocides
- Decreasing/stronger **limited water availability** in semi-aride areas

Challenge

- **Complex and varying water matrix** leading to decrease of efficiency of available water treatment technologies on an insufficient economic/technical level or to damages **preventing water reuse**

Solution

- Use of **innovative technologies** as **capacitive deionisation** and water management (cascade)
- Determination of **concerted combinations** of water treatment **chemicals** (e.g. flocculent, biocide), **solid removal** and **desalting/softening** technologies

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Focus - Holistic view of a site including water sources

- Reuse of low loaded waste/process water in a cascade considering the required water qualities
- Recycle of loaded waste/process waters as e.g. back wash water from sand filters by e.g. solid and salt removal for an internal reuse
- Use of alternative water sources as sea water and rain water or the optimization of river water treatment by using innovative desalting technologies as the capacitive deionization

Aims

- Decoupling of production from fresh water utilization
- 20% fresh water saving by reuse process water and further 38% by desalination technologies
- 90% reduction of wastewaters by treatment of backwash water
- Recovery of 20% heat losses from cooling water by using chemical heat pump technology
- Minimization of fresh water use per ton of steel of 50% by using alternative water resources

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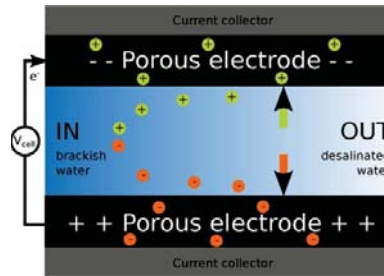
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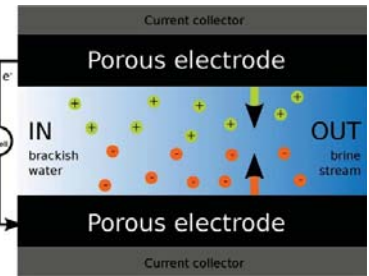
Innovative technologies

Innovative Technologies: Capacitive deionisation (CDI)

- Ion removal by electrostatic adsorption at electrodes and subsequent desorption during regeneration
- Low energy demand compared to RO and IE
- Capacity:
 - lab: 60 - 210 l / h
 - pilot: 1.000 – 2.000 l / h
- Variable parameters:
 - Flow rate: clean water, backwashing water
 - Times: desalination, backwash, rinsing
 - Current (up to 60A)



Desalting



Regeneration



Lab CDI



Pilot CDI

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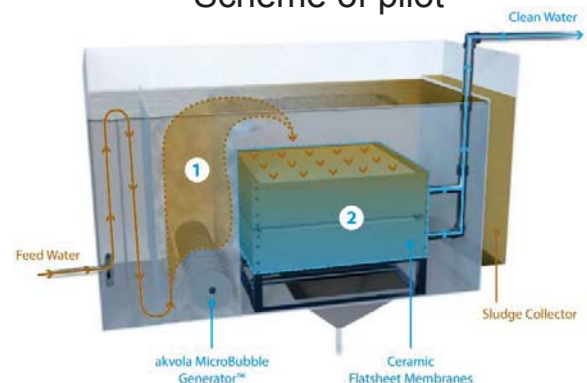
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Innovative Technology: Dissolved Air Flotation with Microfiltration

- First time application for removal of high loads of suspended solids (g/L) and oil in filter back washing water
- Principle: suspended solids removal by enhanced air flotation
- Low footprint on a sustainability way
- Capacity:
 - lab: batch.
 - pilot: 5000 l / h
- Pilot unit has submerged ceramic membrane
- Variable parameters:
 - Chemical pretreatment
 - Flux, air flow rate
 - Frequency backwashes

Scheme of pilot



Lab flotation



Pilot Flotation

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Results

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Results: CDI River water/back wash water

Determined main limiting component and requirements for internal reuse

- Conductivity/salt content: < 200 $\mu\text{S}/\text{cm}$, chloride < 100 mg/L
- Organic/oil content: < 5 mg/L, hardness: < 200 mg/L
- Solid content: < 5 – 20 mg/L

Investigated media

- Back washing water conductivity: 1000 $\mu\text{S}/\text{cm}$
- River water: conductivity: 250 $\mu\text{S}/\text{cm}$

Achieved results with CDI

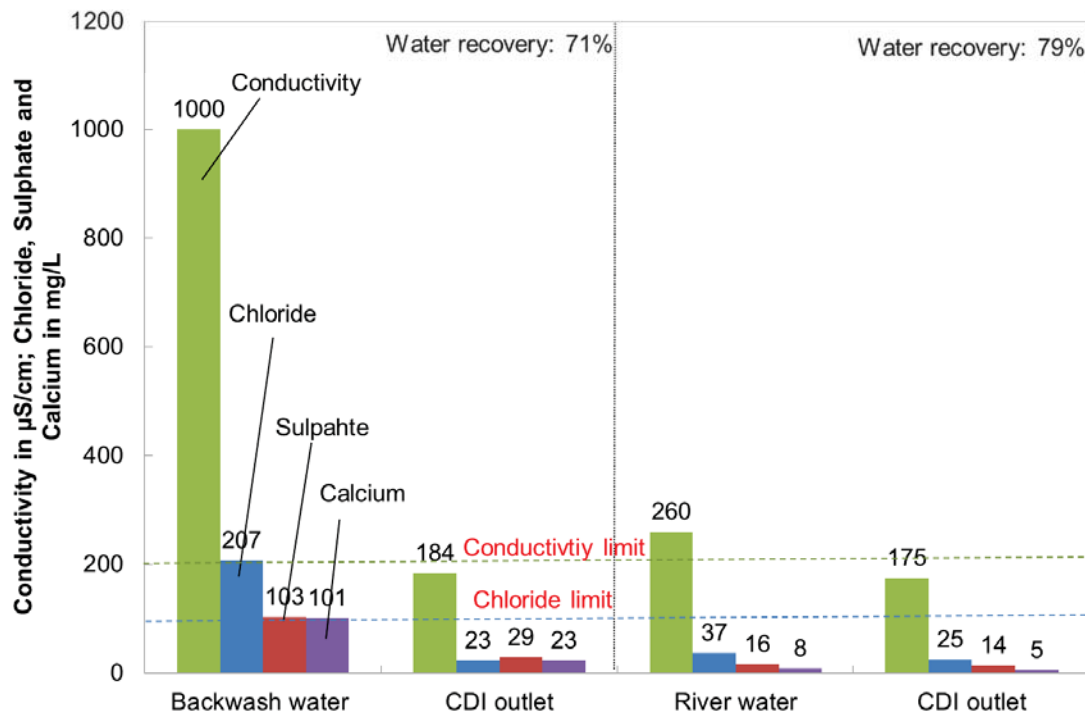
- Fulfilling AM requirements
- Water recovery - river water: 79%, back wash: 71%
- Removal efficiencies: Cl/hardness 88%, sulphate 66%, conductivity about 81%
- Max. desalting: 46 $\mu\text{S}/\text{cm}$ (demineralized water: 10 $\mu\text{S}/\text{cm}$) with water recover of 66% and energy demand of 0.97 kWh/m³
- No disturbing effect of used cooling water treatment chemicals

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Results: CDI treatment of river/back wash water



- Full filling of AM requirements regarding water composition by CDI treatment of backwash water and river water

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Results: Use of back wash water and river water after CDI treatment

		Back wash water	River water
Hot Rolling Mill	Reheat furnaces	pH adjustment	
	Equipment cooling		
	Direct cooling		
Continuous Casting Circuits	Mould cooling	pH adjustment necessary	
	Contact cooling		
Electric Arc Furnace	Indirect closed cooling	Further softening required	
	Open cooling		
Converter Circuits	Indirect cooling		
	BOF gas cleaning	pH adjustment	
Blast Furnace Circuits	Indirect cooling		
	Gas cleaning	pH adjustment necessary	
	Slag granulation		

- CDI treated river water can be directly for all applications beside indirect closed loop cooling at the electric arc furnace
- Direct use of CDI treated back wash water in: cooling processes in hot rolling mill, EAF and blast furnace possible - pH-adjustment from 6.5 to 7 or 7.5 necessary for further applications

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Results: Solid/oil removal from back wash water by flotation/filtration

Determined main limiting component and requirements for internal reuse

- Oils and grease content (< 5 mg/L)
- Solid content (< 10 mg/L) and Turbidity (< 1 NTU)

Investigated media

- Backwash water (Turbidity 20-60 NTU)

Achieved results with dissolved air flotation combined with microfiltration

- Fulfilling RO and CDI requirements
- Water recovery: 94%
- Removal efficiencies: Turbidity 99%, TSS 99%, Oils and grease 85%
- Backwash every 120 min for 30 s
- Coagulant dosage: 5 mgFe/L



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Results: Solid removal from Sea water by Multimedia filter / UF

Determined main limiting component and requirements for RO use

- Turbidity (< 1 NTU)
- Solid content (< 10 mg/L)
- Organic/oil content (< 5 mg/L)

Investigated media

- Sea water: conductivity: 48000 μ S/cm, 11 NTU, Solid content 115 mg/L

Tested technologies: Multimedia filters and Ultrafiltration



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Results: Solid removal from Sea water by Multimedia filter / UF

Achieved results with ultrafiltration (UF) and multimedia filters

- Multimedia filters:
 - Best conditions: Sand+Antracite+Garnet at 20 m/h
 - No fouling of the media was observed
 - Turbidity removal, 80%, 0.7 NTU
- Ultrafiltration:
 - Constant outlet quality
 - No fouling observed
 - Turbidity removal, 90%, 0.3 NTU



Results: Sea water desalting by RO

Determined main limiting component and requirements for internal reuse

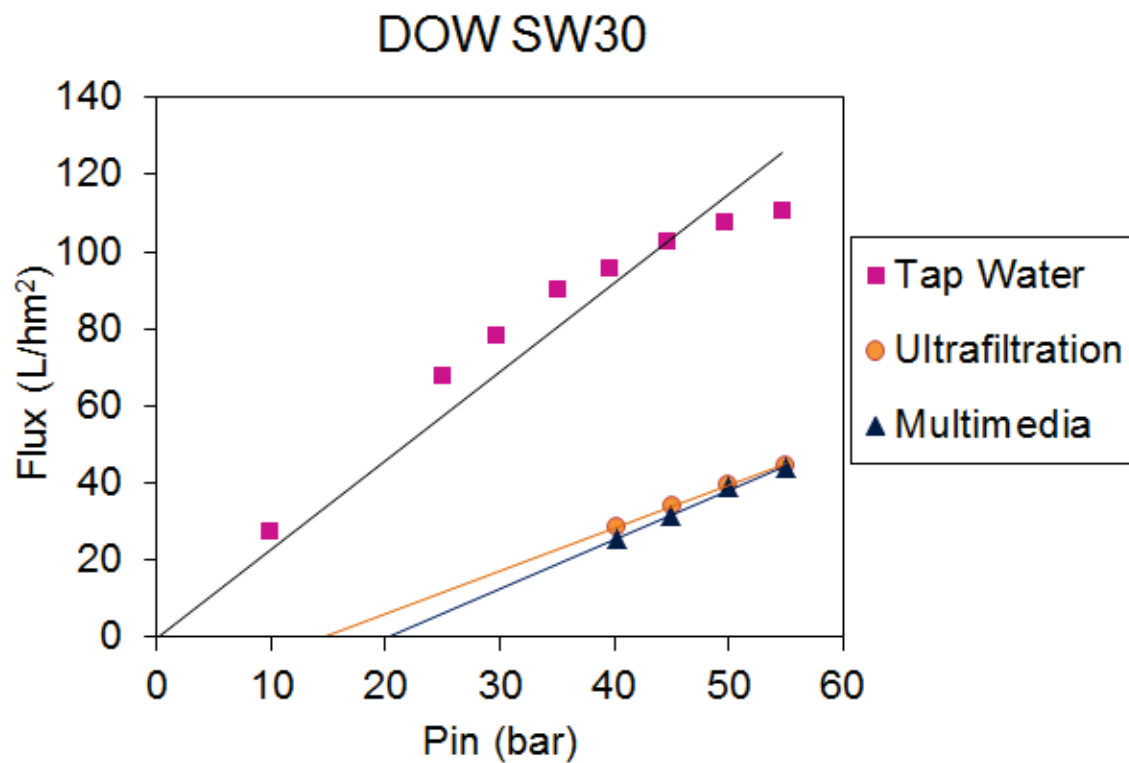
- Conductivity/salt content: < 200 $\mu\text{S}/\text{cm}$, chloride < 100 mg/L
- Hardness: < 200 mg/L

Investigated media

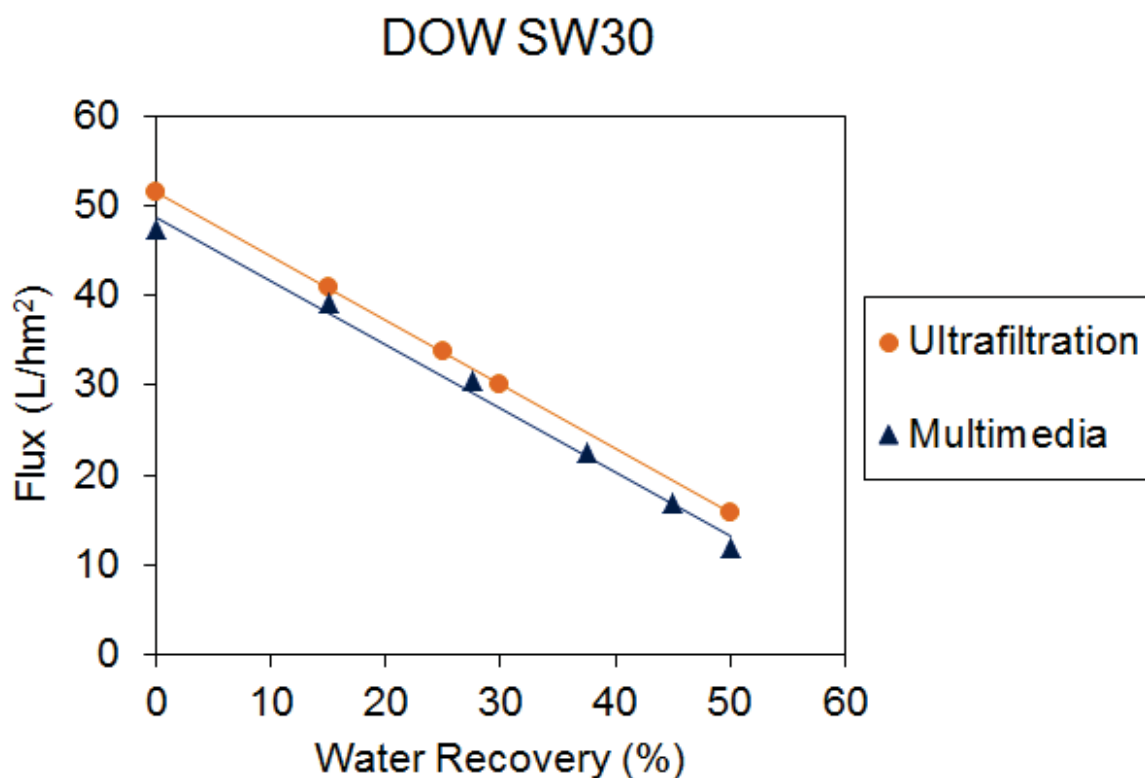
- Pre-treated sea water by multimedia and ultrafiltration

Achieved results with RO

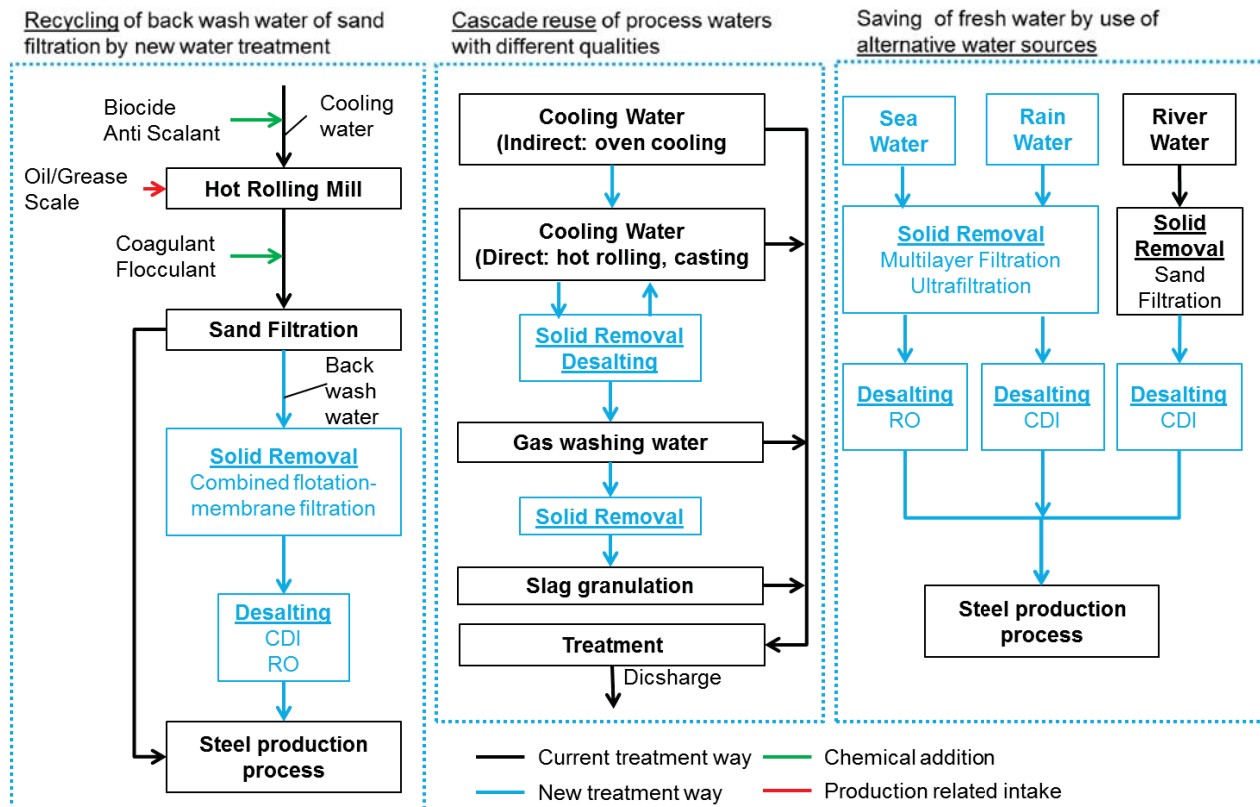
- Higher osmotic pressure (+5bar) for multimedia pretreatment. This means that +5bar are needed to be applied for the pretreated water based on multimedia filter.
- In terms of flux, 10% lower flux was obtained for multimedia pretreated water at the same conditions.
- No effect on fouling was detected for neither of the two pretreatment.
- One pass (Chlorides = 1200 mg/L and conductivity = 1500 $\mu\text{S}/\text{cm}$)
- Two passes are needed to achieve AM requirements (Chlorides = 50 mg/L).



Effect of pre-treatment and water recovery



Applications: recycling, cascade use, alternative water use



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Outlook - contact

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2018

- Ion exchange and reverse osmosis experiments and simulation for river water
- Performance of CDI and RO trials of back washing water treated with flotation

2019

- Preparation of demonstration in real operational environment of selected technologies for the treatment of selected water streams
- Performance of demonstration

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THANK YOU!



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Efficient water use in steel industry by innovative and sustainable solutions

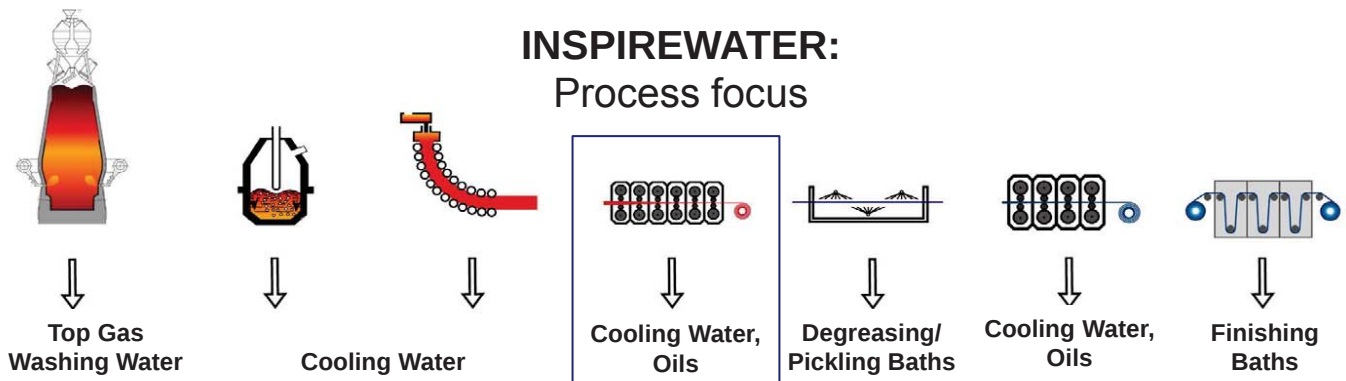
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Situation - Solutions - Aims



Water use in steel industry

- Cooling applications (material: casting, hot rolling; machines): 75%
- Gas washing (blast furnace, basic oxygen furnace): 13%
- Material conditioning (e.g. slag granulation): 12%

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Situation

- **Process related intake** of solids (Fe, carbon) and organic (oil/grease) causing wear and enhancing biological activity
- Concentration of **salts/hardness** components leading to **corrosion and scaling**
- **Addition** of corrosion inhibitors, antiscalants and biocides
- Decreasing/stronger **limited water availability** in semi-aride areas

Challenge

- **Complex and varying water matrix** leading to decrease of efficiency of available water treatment technologies on an insufficient economic/technical level or to damages **preventing water reuse**

Solution

- Use of **innovative technologies** as **precipitation reactor** (softening, disinfection) and magnetic separator (chemical free and energy saving solid removal)
- Determination of **concerted combinations** of water treatment **chemicals** (e.g. flocculent, biocide), **solid removal** and **desalting/softening** technologies

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Focus

- **Decoupling** of **production** from **fresh water** utilization

Project aims

- **Decrease of corrosion and scaling** by use of suitable technologies for **longer water use** reducing the freshwater demand/waste water occurrence
- **40% fresh water saving** and waste water reduction by removal of solids, salts and hardness components
- **90% energy saving** by use of pressure less solid separation

Innovative technologies



Magnetic separator



Covered magnets



Samples

- **Chemical free and pressure less** solid removal with permanent strong field magnets
- **High concentration of particles** in sludge about factor 250 to 1000 compared to influent content
- **Solids contents** in sludge up to **30 wt.-%**
- **Low backwashing water**: Magnetic separator 0.06% - Sand filter: 3 - 5% of treated volume flow
- **Low space demand** (height: 3.15 m, width: 1.47 m, length 1.90 m for 50 m³/h plant)
- Reduction of energy demand (no operation pressure needed)
- **Constant outlet particle content** despite fluctuating inlet particle content
- Reduction of disposal costs by internal **metallurgical re-use** of separated iron containing particles as ore or scrap substitute



Installed at AM



Further application

Type

- Innovative electro-precipitator reactor (TPL-160 by TRIENXIS)

Principle

- Transmission of **high-frequency electrical pulses with sharp oscillations**
 - provoking high variability in the water chemistry
 - changing the forces of repulsion balance

Effect

- Hindrance for living forms adaptation (**biocide effect**)
- **Modification** of **solid precipitation** by
 - transforming typical precipitate into a non-sticking “dust” allowing
 - **faster** and controlled way flocculation

Added value expected:

- **Decrease** in **chemicals** consumption
- **Decrease** of **corrosion, scaling and biofouling**

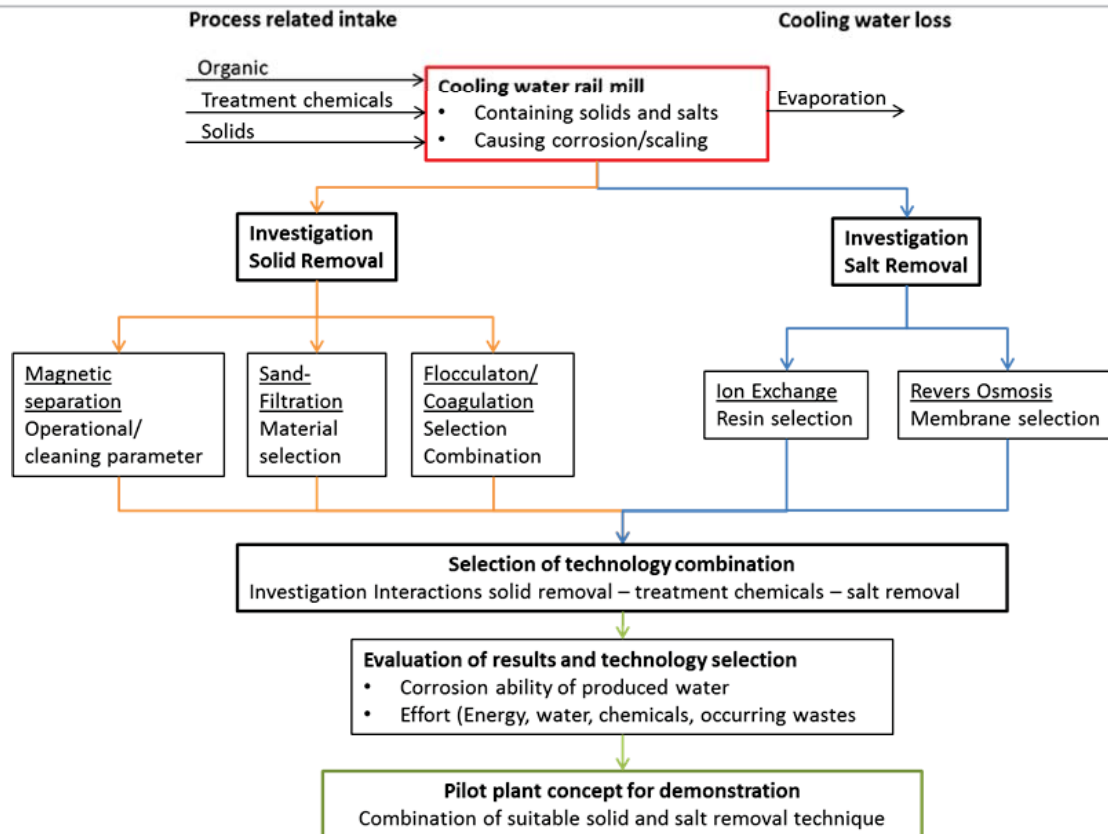
Operational conditions

- Constant flow around 1100 m³/h
- Laminar flow required
- Reactor must always be filled out completely with water
- Equipment is implemented at the indirect close cooling circuit of Rail Mill reheating furnace

Tests and measurements

- Blank tests (reactor switched off, 3 months) and operational tests (reactor switched on, 3 months)
- Water and other analyses:
 - Corrosion measurements: LPR probe & corrosion coupons
 - Water samples analysed weekly: pH, conductivity, alkalinity, residual chlorine, suspended solids, sulphate, chloride, orthophosphate, hardness, calcium, magnesium, iron

Results



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Magnetic separator



Reverse Osmosis



3-layer-filtration



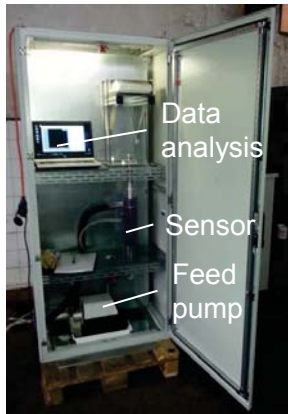
Innovative Reactor

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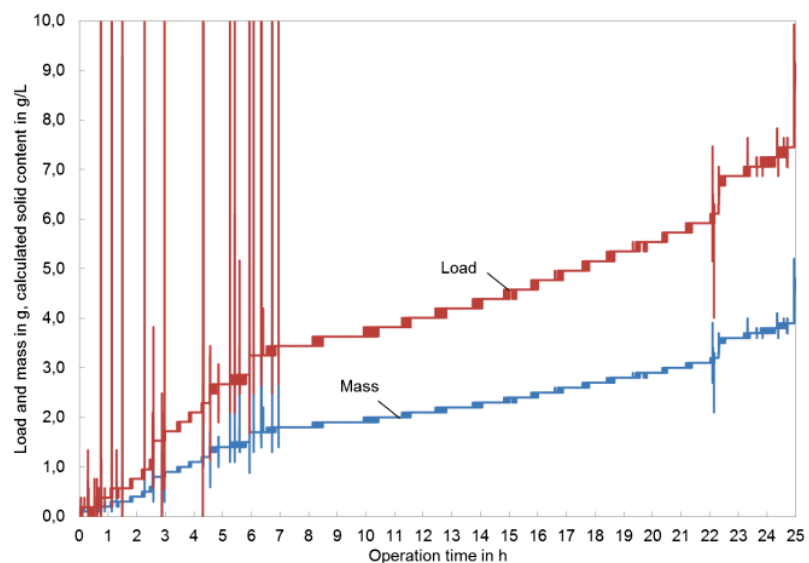
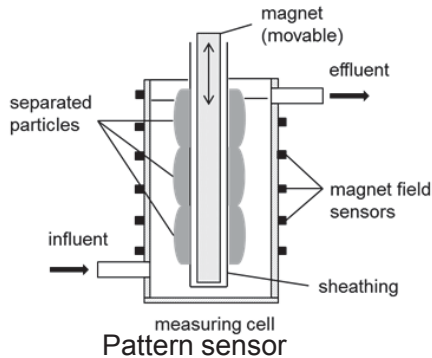
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Sensor at demonstration



Typical measurement curve

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Situation

- **Strongly varying solid contents and required measurement ranges** in cooling and gas washing waters (10 mg/L – 30.000 mg/l)
- **Conventional technologies not or only limited useable** because of colouring, variation of ion content, temperature or pH-values

Principle

- **Separation of magnetic particles** at magnet/sheeting surface and **quantification**

Applications

- Tailored dosage of flocculants/coagulants, process control blast furnace

Focus in INSPIREWATER

- Determination of correlation magnet load sensor - magnetic separator for tailored magnet cleaning

Result

- **Prolonging period between two cleanings up to factor 2 - 3**, in maximum to factor 7 -> decrease of water use up to 50% to 85%

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Turbidity removal:

- 92% and 98% after < 2 h operation

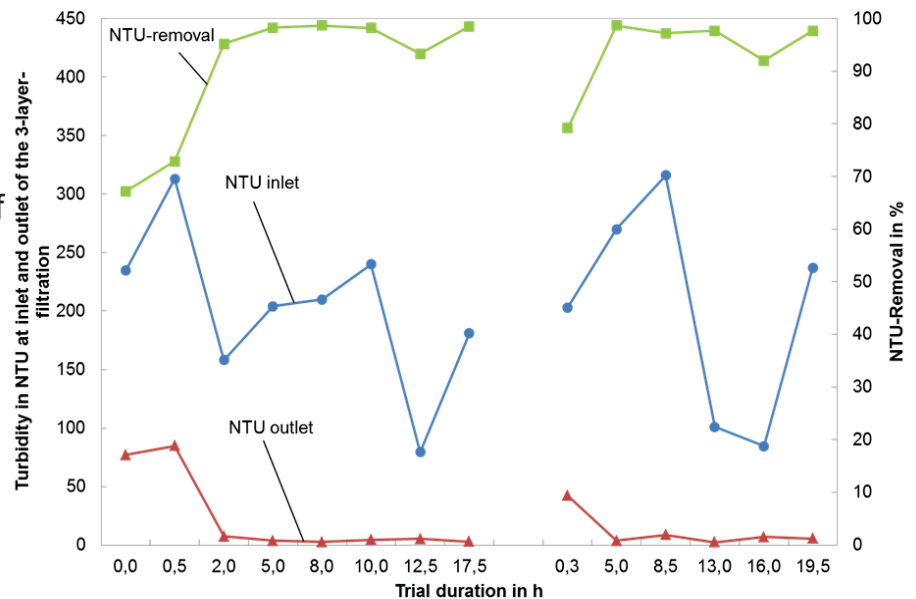
Flushing time

- 13 min sufficient
- Achievement of turbidity of 14 -20 NTU close to operational water (3 – 5 NTU)

- Solid content: 6 – 14 mg/L

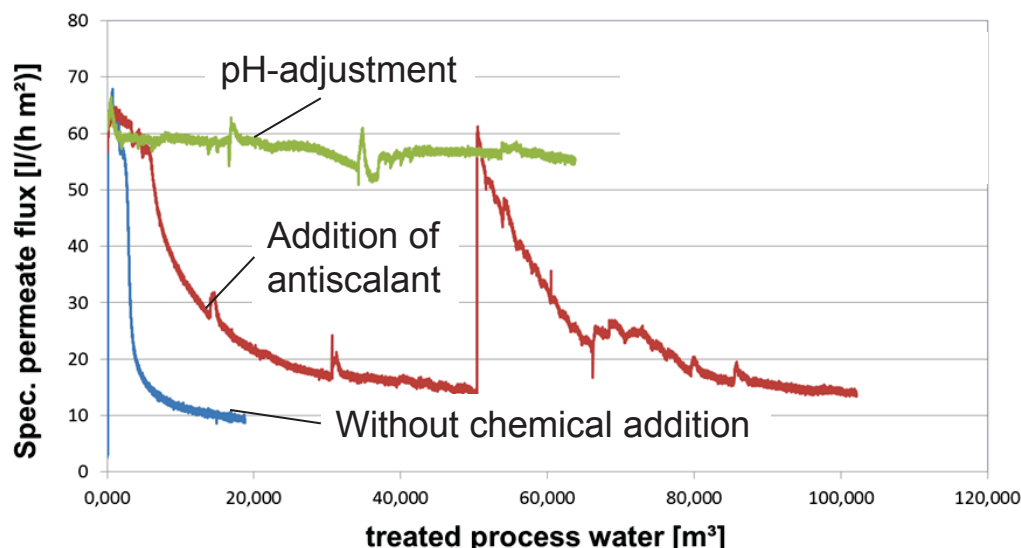
Confirmation of lab results

- Optimum linear velocity: 15 m/h (currently 25 m/h)
- 3-layer filtration media: sand/anthracite/garnet is the optimum for efficiency



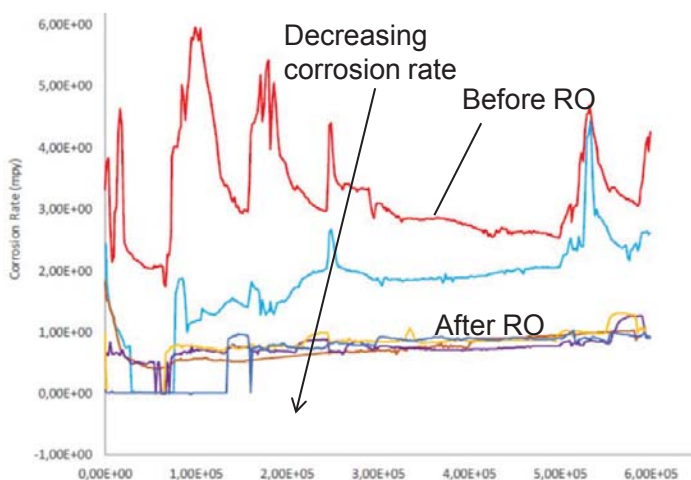
Varied parameter

- Technology for solid removal as pre-treatment: magnetic separator, 3-layer-filtration, sand filter
- pH – value (acid addition)
- Dosage of antiscalant with different concentrations
- Concentration factor RO (4, 10)

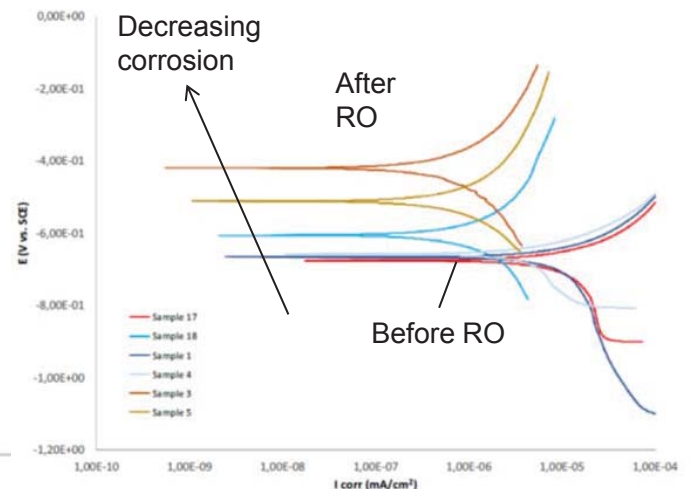


Results

- **Suitable conditions:** concentration factor 4 (water recovery 80%), 30 bar
- Nearly **constant flux** by continuously **addition** of **sulphuric acid**
- About **100 % retention** of **chloride/sulfate** and conductivities of 5 $\mu\text{S}/\text{cm}$
- **Removal hardness** forming components from 3.8 **to < 1 mmol/l**
- **Combination solid removal – RO suitable** for cooling water treatment
- **pH adjustment or softening mandatory** for avoiding flux decrease because of scaling



Measure curves corrosion rate
(Tafel plot)



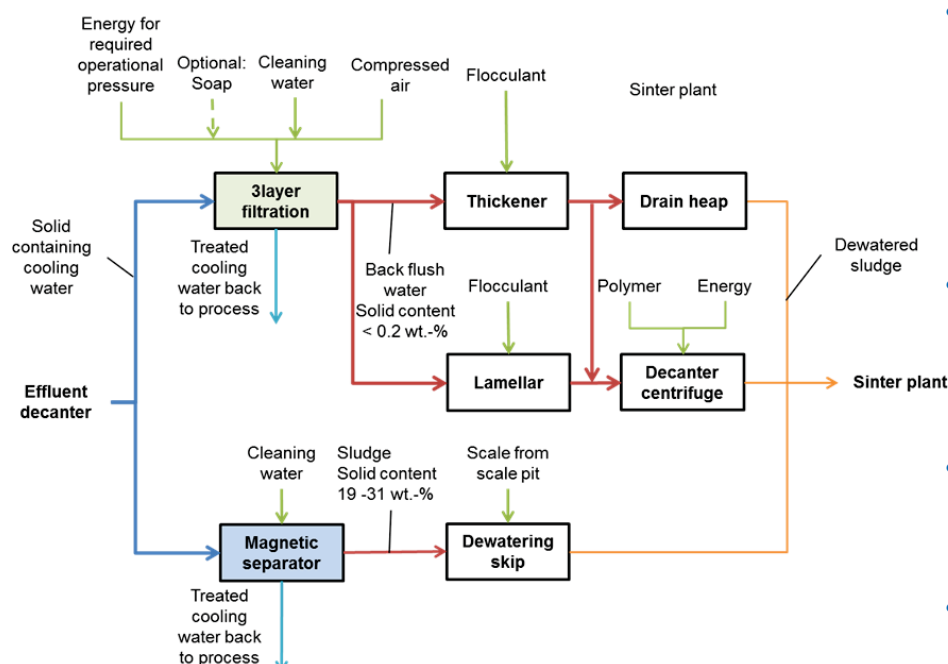
Measure curves corrosion potential
(Rp/EC-trend)

Analysis method

- Tafel plot and R_p/E_c -trend

Results

- Significant decrease** of **corrosion** potential and corrosion rate **by RO treatment**
- No influence of solid removal technology** to corrosion potential or corrosion rate
- No influence of antiscalant** to corrosion rate **but decreased if H_2SO_4 is dosed**



- Determined ratio amount sludge/treated water:**
 - MS: 0.001 - 0.006;
 - 3-layer-filtration: 1.4 - 4.3
- More than **100times higher solid contents in sludge** by using **magnetic separator**
- Effect: **reduced post-treatment** effort for dewatering
- No auxiliary materials** except of water needed by using magnetic separator

Results

- Demonstration performed for 6 month, three month before schedule started
- **Magnetic separator:**
 - Treatment of approx. 31,000 m³ with achievement of outlet solid contents down to 10 – 15 mg/L (detection limit for solids: 10 mg/l)
- **3layer filtration:**
 - Confirmation of lab results – field trial turbidity removal between 92% - 98% compared to lab trials (turbidity removal: 90%) for a flow velocity of 25 m/h.
- **Reverse osmosis:**
 - Combination solid removal – RO suitable for cooling water treatment
 - Concentration factors up 4 with dosage of acid allows stable flux close to initial flux
 - Decrease of corrosion ability similar to lab trials

Outlook

- Continuous demonstration of **innovative reactor** in industrial trials

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