



## Constant Waterlevel Sequencing Batch Reactors

# CWSBR®

### CONTENT

<b>1</b>	<b>CWSBR® CONSTANT WATERLEVEL SEQUENCING-BATCH-REACTOR</b>	<b>2</b>
<b>1.1</b>	<b>Basics</b>	<b>2</b>
1.1.1	Pond Treatment Systems	2
1.1.2	Extension of Pond Treatment Plants	2
<b>1.2</b>	<b>SBR-Technology</b>	<b>3</b>
1.2.1	Advantages of SBR-Technology	4
<b>1.3</b>	<b>From Pond to SBR-Plant</b>	<b>4</b>
<b>1.4</b>	<b>The CWSBR®-Process</b>	<b>6</b>
1.4.1	The Stages of the CWSBR®-Process	6
1.4.2	Plant Scheme	7
1.4.3	Characteristics of the CWSBR®-Technology	9
1.4.4	Process Engineering	9
1.4.5	Investment Costs	9
<b>1.5</b>	<b>Parallel Process</b>	<b>10</b>
<b>2</b>	<b>REFERENCE PROJECTS</b>	<b>11</b>
<b>2.1</b>	<b>Sewage Plant of Fockenbachtal, 3,200 PE</b>	<b>11</b>
2.1.1	Plant Data	11
2.1.2	Purification Results	12
<b>2.2</b>	<b>Sewage Plant of Guelzow, 3,000 PE</b>	<b>13</b>
2.2.1	Plant Data	14
2.2.2	Purification Results	14
<b>2.3</b>	<b>Sewage Plant of Krummesse, 4,800 PE</b>	<b>15</b>
2.3.1	Reconstruction Measures	16
2.3.2	Plant Data	17
2.3.3	Purification Results	17
<b>2.4</b>	<b>Sewage Plant of Dalian, 130,000 PE</b>	<b>18</b>
2.4.1	Plant Data	19
2.4.2	Purification Results	19
<b>3</b>	<b>CONCLUSION</b>	<b>20</b>
<b>4</b>	<b>REFERENCE LIST</b>	<b>21</b>



## **1. CWSBR® Constant Waterlevel Sequencing-Batch-Reactor**

- The treatment technology for extension and rehabilitation of pond treatment plants
- 70 % and more capacity extension
- 60 % and more costs saving in comparison to new construction
- Utility rate of existing constructions over 90 %

### **1.1 Basics**

#### **1.1.1 Pond Treatment Systems**

From the 1960s to 1980s, aerated and non-aerated pond treatment systems (aeration lagoons) were constructed to cover various demands. Aside the most common use, to treat domestic wastewater in rural areas, these plants were also used for the treatment of specific industrial wastewater.

Pond treatment systems imply the disadvantage of a diminishing nitrification rate due to the slow growth of the nitrobacteria. This low nitrification rate results in an only partial denitrification at the pond's ground, where biomass occurs in anoxic conditions with a high sludge age. To eliminate phosphorous, chemical precipitation is necessary. For the extraction of suspensa, large-scale polishing ponds or plant beds have to be installed.

The task for a new generation of pond treatment systems is therefore clearly defined: The establishment of an extensive wastewater treatment system within the borders of the existing plant, which not only meets the increased regulations but also copes with the increasing wastewater quantity.

#### **1.1.2 Extension of Pond Treatment Plants**

Due to the increasing regulations for wastewater treatment the demand of plant rehabilitations and/or extensions rises.

A large number of pond treatment systems, built in the past twenty years, are in need of an upgrade for various reasons. In general, the upgrade increases the current size by 20 to 50 %.



The most common technical solutions for upgrading current plants are:

<b>Expansion and Upgrading</b>	<b>Estimation of Total Costs</b>	<b>Measure of Success</b>	<b>Possibility of Continuous Cleaning</b>
<b>Construction of an additional pond</b>	approx. 140 €/PE	70 %	No
<b>Construction of a trickling-filter plant</b>	approx. 260 €/PE	80 % - 90 %	Partial
<b>New construction of an activated-sludge unit</b>	approx. 400 €/PE	100 %	Yes

These solutions always imply the construction of new units typically covering 50 % to 70 % of the total costs. However, due to the present financial situation of most communities, the construction of new wastewater treatment plants is decreasing in spite of high effluent charges.

This makes a technical solution with low constructions costs of need. Additionally, this new solution has to comply with today's and future regulations for wastewater treatment, including nitrification, denitrification and biological phosphorus elimination. The treatment of wastewater in a sequencing batch reactor provides a solution.

## **1.2 SBR-Technology**

The main idea of the Sequencing Batch Reactor (SBR) technology is to minimize the impact of hydraulic fluctuations of the wastewater inflow in order to precisely calculate and implement the duration of each process stage.

The SBR technology consists of separate process steps from filling to reaction, sedimentation and discharge, together adding up to one cycle. The single steps are run in a defined timely sequence and repeated periodically. The step-durations depend on the individual elimination goal and can be adjusted to different wastewater types. Aside carbon-elimination, the applied strategy achieves nitrification, denitrification and phosphorus-elimination.

An SBR-plant basically consists of a holding tank, where the permanent wastewater inflow is temporarily stored. From here wastewater flows to the SBR-tank to start a new treatment cycle. A cycle ends with the flow of treated wastewater from the SBR-tank to a balancing tank from which it is constantly discharged to the water body.



### **1.2.1 Advantages of SBR-Technology**

- In comparison to conventional treatment plants, SBR-technology requires fewer constructional and technical measures, in turn saving construction costs, expense, energy and personnel
- Elimination of hydraulic fluctuations in the treatment stage
- “Biocoenotical and economical system-optimisation”: development of process- and selection-strategies to optimize flocculation, avoid bulking sludge and stimulate the enrichment of preferred micro organisms by varying the reaction process.

### **1.3 From Pond to SBR-Plant**

SBR-technology is not directly applicable to a pond treatment plant, due to the process-dependent variable water levels. Just as in a continuous flow plant the waterlevel has to be constant. At the same time, the changing volumes of the holding tank, the SBR and the balancing tank have to be considered.

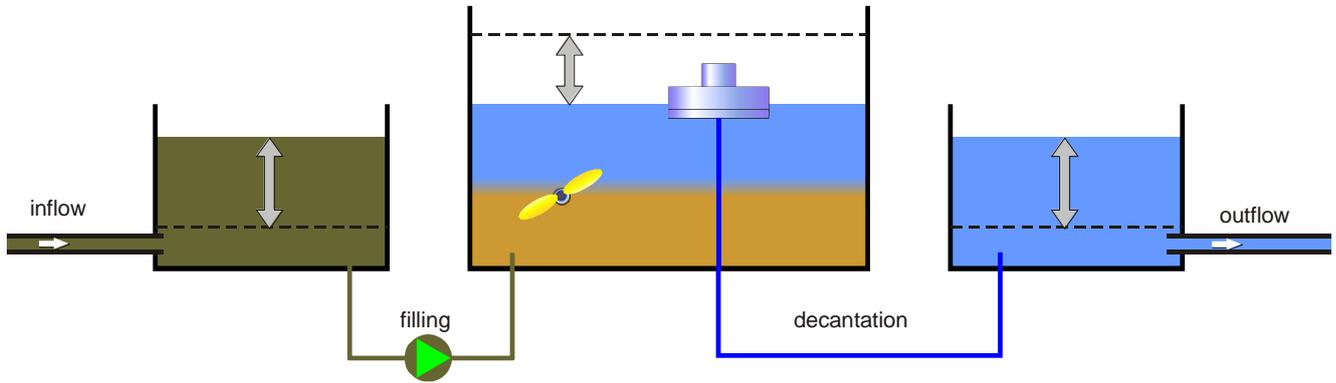
Resulting, the solution is a symbiosis of the present known technologies of SBR and conventional wastewater treatment.

**„The CWSBR®-process uses the advantages of the known techniques simultaneously eliminating their disadvantages.“**

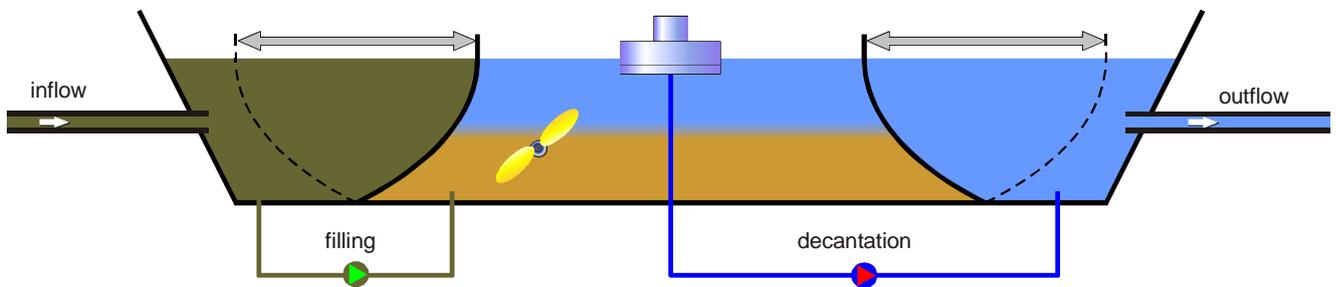
In contrast to conventional SBR-technology the changes of volume are performed horizontally, not vertically.



**Standard SBR-Process**



**CWSBR<sup>®</sup>-Process**



**Fig. 1: SBR- and CWSBR<sup>®</sup>-process**



## 1.4 The CWSBR®-Process

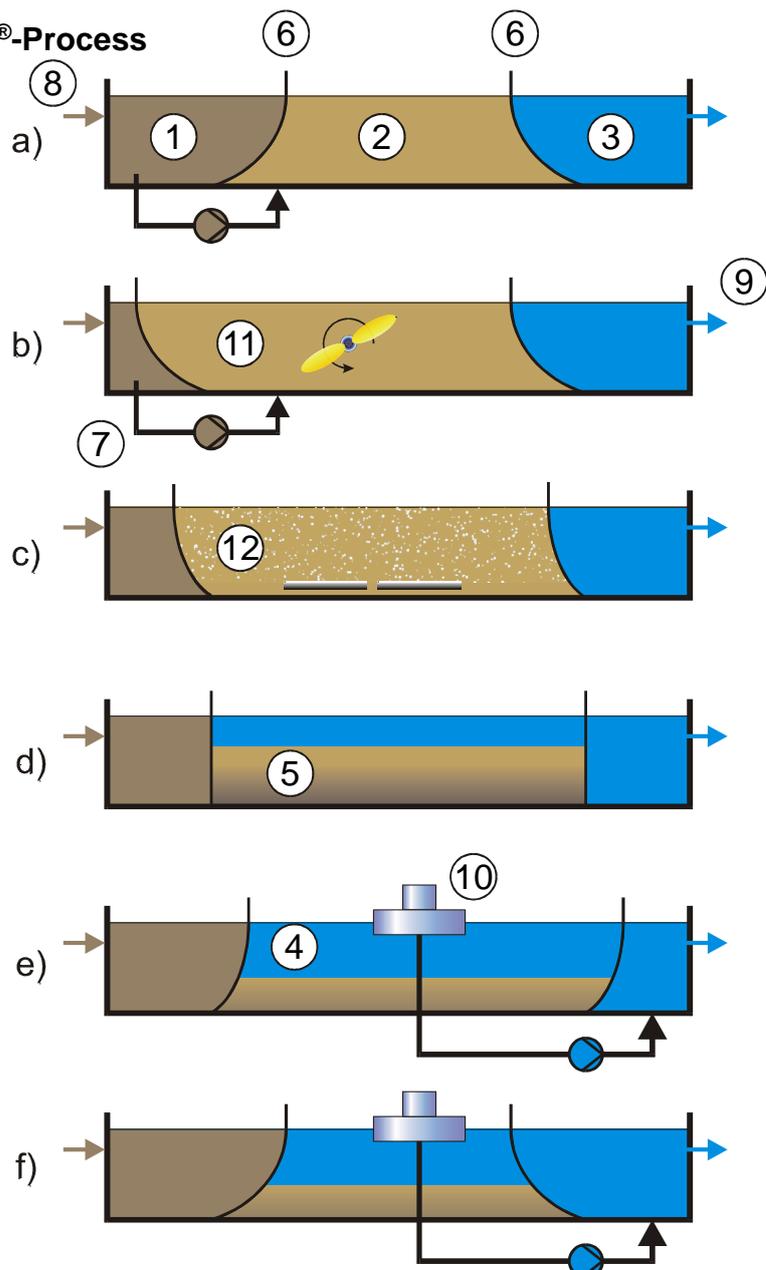
The difference between the classical and innovative CWSBR® (Constant Waterlevel SBR) process lies in the elimination of the pending water level. This is achieved with specially developed Hydro Sails dividing the pond into holding, SBR and balancing zone.

The following figure describes the basic stages of a cycle, indicating the constant water level at each stage with a constant inflow and discharge volume.

### 1.4.1 The Stages of the CWSBR®-Process

CWSBR®-cycle	
a)	filling of the reaction chamber is initiated by pumping the water from the holding to the SBR zone
b)	initiation of the carbon, nitrogen, and phosphorous elimination process
c)	biological treatment
d)	initiation of settling phase
e)	discharge of treated effluent
f)	end of decanting phase

Description	
1	holding zone
2	SBR / reaction zone
3	balancing zone
4	clear water
5	activated sludge
6	Hydro Sail
7	filling of SBR-zone
8	inflow
9	discharge
10	decantation
11	mixing
12	aeration

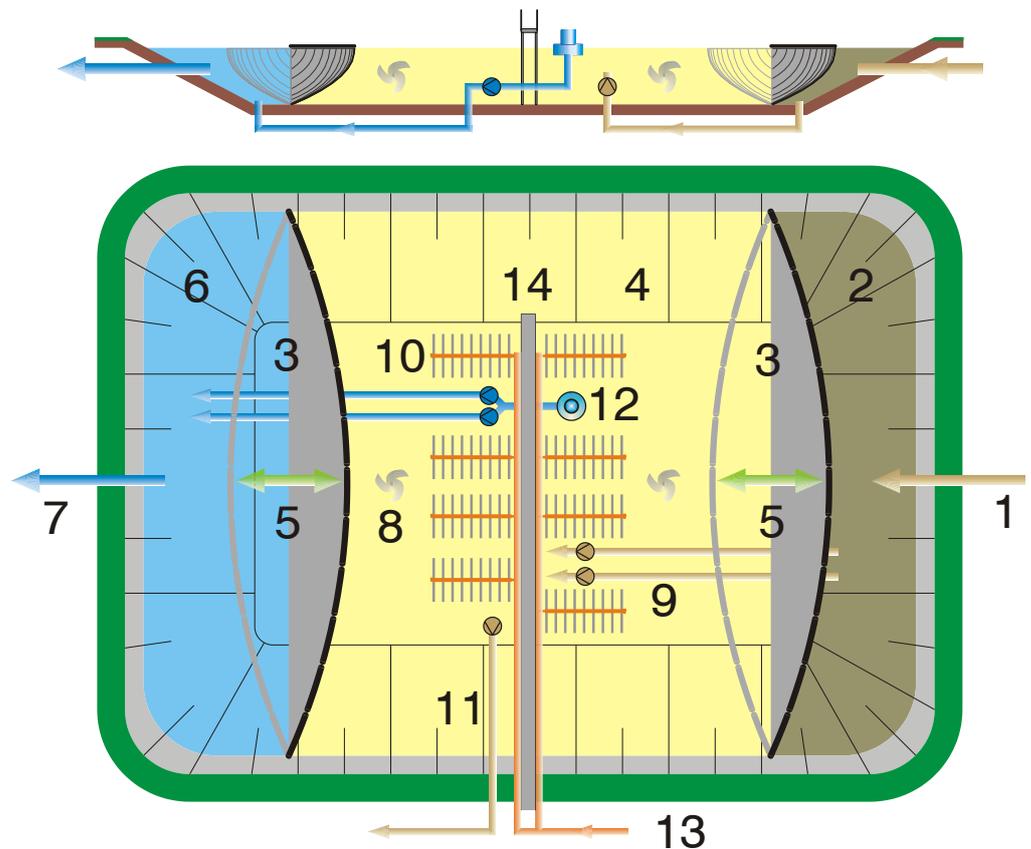


**Fig. 2: Treatment Cycle of the the CWSBR®-Process**



### 1.4.2 Plant Scheme

Fig. 3 shows a CWSBR<sup>®</sup>-plant. The central volumen (4. SBR-zone) is the actual reaction zone, where the biological wastewater treatment processes take place. The main difference to a conventional pond system is that the biological reactions are defined and controlled and do not occur merely at random, enabling CWSBR<sup>®</sup>-plants to meet binding values. The Hydro Sails allow an optimised usage of the volume at disposal, reducing construction costs to approx. 15 %.



Description	
1	inflow
2	holding zone
3	Hydro Sail
4	SBR-zone
5	working area of Hydro Sail
6	balancing zone
7	effluent
8	mixer
9	feeding pump
10	aeration system



11	excess sludge pump
12	effluent discharge/pump
13	air supply
14	gangway

**Fig. 3: Scheme of the Conversion of Pond Treatment Plant into a CWSBR®-Plant**



### **1.4.3 Characteristics of the CWSBR®-Technology**

- Short implementation time due to low construction volume
- Reduced sludge disposal costs as high-cost pond desludging every 5 to 7 years is substituted through continuous sludge stacking
- Application of the highly effective SBR treatment process
- High treatment degree allows substantial savings of municipal effluent charge
- No process-related fluctuations of the water level
- Reduced energy demand for process-related pumping (approx. 65 %), due to minimized hydraulic losses through water level differences
- Continuous outflow
- Regulation of outflow quantity not necessary
- Optimised design of aeration and agitator equipment, as there is no water level fluctuation (SBR process: minimum water level approx. 30 % below maximum water level)
- Reduction of the total necessary tank (pond) volume, as retention of cycle volume in holding and balancing zone is not required.
- Reduction of treatment time during the sedimentation and decantation phase, as it is no longer necessary to consider the water level decrease velocity
- No pond-typical winter problems

### **1.4.4 Process Engineering**

Depending on the local conditions the usage of the existing pond structures leads to a 40 to 70 % capacity increase. Additionally the following treatment processes can be achieved:

- Nitrification
- Denitrification
- Elimination of phosphorus through biological processes and sedimentation
- Thoroughly digested sludge ( $t_{TS} = 25$  d)

### **1.4.5 Investment Costs**

The advantage of the CWSBR®-process in comparison to new constructions is the significant savings achieved through the integration of already existing structures. The saving potential not only lies in the cutback of construction material but also in the usage of the existing ponds without extensive and thus expensive reconstruction.

The CWSBR®-process enables the fulfilment of binding values in the long run, thus granting the operator a maximum design security.



The CWSBR®-process integrates the highly efficient SBR-technology in existing pond treatment plants, using approx. 90 % of the existing structures. Due to the low construction ratio, the total costs lie between approx. 75 and 150 €/PE<sub>ext</sub>.

## Exemplary Investment Costs: Extension of a Pond System from 1,400 to 2,000 PE

	New construction of a SBR Plant	CWSBR®-Process
<b>Specific costs</b>	approx. 400 €/PE	approx. 120 €/PE
<b>Total costs</b>	approx. 800,000 €	approx. 240,000 €
<b>Building construction / foundation work</b>	approx.60 % = 240 €/ PE	approx.10 % = 12 €/PE
<b>Mechanical and electrical installation</b>	approx.40 % = 160 €/ PE	approx.90 % = 108 €/PE

### 1.5 Parallel Process

Every CWSBR®-plant is an independent treatment unit, treating the inflow quantity to meet the required discharge values. Parallel process units lead to a precise adjustment of the treatment capacity. Even seasonal capacity fluctuations, such as in wine-producing regions, can be handled with such parallel process units.



## 2 Reference Projects

### 2.1 Sewage Plant of Fockenbachtal, 3,200 PE

One example for the successful implementation of CWSBR<sup>®</sup>-technology is a wastewater treatment plant in Rheinland-Pfalz, WWTP Fockenbachtal. Following the basic evaluation the municipal utility Verbandsgemeindewerke Rengsdorf, as operator, decided to implement a CWSBR<sup>®</sup>-plant. Despite the relatively small plant capacity the investment costs were cut by 68 % in comparison to alternatives. Due to the good existing structures and a tight time schedule, operation was started after only 4 months of construction. A new distribution unit was constructed for the storm water management. Here all hydraulic conditions are regulated with a special controlling software. The existing pond 1 is now used as a regular storm water tank with overflow. Consequentially this leads to a dynamic management of the CWSBR<sup>®</sup>-plant and optimized purification results for all operational states.



**Fig. 4: Operation during Winter, Air Temperature: -9 °C**

#### 2.1.1 Plant Data

Existing plant	Two-step pond system	2,400 PE
Expansion	CWSBR <sup>®</sup>	3,200 PE
Begin of operation	October 2004	
Operator	Verbandsgemeindewerke Rengsdorf	
Supervisory Authority	Struktur- und Genehmigungsdirektion Nord	



Disposal system	combined system
Dry weather inflow	400 – 630 m <sup>3</sup> /d
Storm weather inflow	1,500 – 6,000 m <sup>3</sup> /d
BOD-load (inflow)	192 kg/d
Phosphorus load (inflow)	6.1 kg/d
Nitrogen load (inflow)	35.2 kg/d
Specific energy demand	0.95 kWh/kg BOD
Construction time CWSBR <sup>®</sup> -plant	6 weeks
Specific costs the CWSBR <sup>®</sup> -plant	120.- €/PE

### 2.1.2 Purification Results

	Unit	Binding Values	Dec. 04 / Jan. 2005	Feb. / Apr. 2005	May / June 2005	June / Dec. 2005
<b>COD</b>	[ mg/l ]	60	26.4	18.2	18.9	14.8
<b>BOD</b>	[ mg/l ]	15	4.8	4.2	4.4	4.2
<b>NH<sub>4</sub>-N</b>	[ mg/l ]	8	0.6	0.1	0.4	0.2
<b>total nitrogen</b>	[ mg/l ]	18	9.9	6.5	3.4	8.7
<b>total phosphorus</b>	[ mg/l ]	2	1.7	1.2	1.8	1.5



**Fig. 5: Balancing Zone Outflow**



## 2.2 Sewage Plant of Guelzow, 3,000 PE

Before reconstruction, the wastewater from the communities of Guelzow and Kollow was treated in a biological filter. Due to a general overload and the resulting exceeding of the legally binding effluent values the rehabilitation of the entire wastewater treatment plant was necessary. Considering not only the binding effluent values but also aspects such as

- Local situation
- Minimising construction and operating costs
- Operational reliability, reduced maintenance costs and
- Necessary operating staff

the following concept was implemented at the wastewater treatment plant in Gülzow:

- Construction of a **CWSBR®-plant**
- Reconstruction of the existing Imhoff tank into a sludge tank
- Installation of a new blower unit
- Construction of a new sludge tank.



**Fig. 6: CWSBR®-Plant**



### 2.2.1 Plant Data

Existing plant	Biological filter
Expansion	CWSBR <sup>®</sup> -plant with 3,000 PE
Begin of operation	July 2006
Operator	Schleswag Abwasser
Supervisory Authority	Kreis Herzogtum Lauenburg
Disposal system	separate system
Daily inflow quantity	510 m <sup>3</sup> / d
Specific energy demand	1.0 kWh / kg BOD
Construction time for CWSBR <sup>®</sup> -plant	6 weeks
Specific costs of the CWSBR <sup>®</sup> -plant	96.- €/PE

### 2.2.2 Purification Results

	Unit	Binding Values	Average Inflow Concentration	Average Outflow Concentration
<b>COD</b>	[ mg/l ]	60	643	22.0
<b>BOD</b>	[ mg/l ]	10	407	4.0
<b>NH<sub>4</sub>-N</b>	[ mg/l ]	15	70.7	0.3
<b>total nitrogen</b>	[ mg/l ]	20		6.8
<b>total phosphorus</b>	[ mg/l ]	1.2	12.5	0.6



### 2.3 Sewage Plant of Krummesse, 4,800 PE

The sewage plant of the municipalities of Krummesse and Klempau was constructed as a 4-pont treatment plant in 1982. Two of the ponds were aerated.

The necessary increase of capacity and the required increased cleansing capacity made the reconstruction of the plant obligatory. The backfilling the first aerated pond reduced its volume to the necessary size. This refilled area was then used as platform for the new sludge tank. Due to the reconstruction, the required ground space of the entire plant was reduced by more than 60 %.



**Fig. 7: Krummesse before; 1. aerated pond**



### 2.3.1 Reconstruction Measures

- Newly constructed inflow with volumetric flow measurements
- Construction of a building for the primary treatment stage
- Construction of a new grit chamber
- Conversion of the 1. pond into a **CWSBR®-pond**
- Construction of a sludge tank on the backfilled surface of the 1. pond
- Installation of a new blower station within the existing operation building
- Installation of a new precipitant station
- Renewal of the entire electro- and controll-technics



Fig.8: Krummesse after reconstruction



### 2.3.2 Plant Data

Existing plant	two-step aereated pond treatment plant
Expansion	CWSBR®-plant with 4,800 PE
Begin of operation	Feb. 2007
Operator	Schlesweg Abwasser
Supervisory Authority	Kreis Herzogtum Lauenburg
Disposal system	combined/separate system
Daily inflow quantity, dry weather	528 m <sup>3</sup> / d
Daily inflow quantity, storm water	1.302 m <sup>3</sup> / d
Specific energy demand	0,91 kWh / kg BOD
Construction time for <b>CWSBR®-plant</b>	7 weeks
Specific costs for <b>CWSBR®-plant</b>	101,- €/PE

### 2.3.3 Purification Results

	Unit	Binding Values	Average Inflow Concentration	Average Outflow Concentration
<b>COD</b>	[ mg/l ]	60.0	673.0	18.2
<b>BOD</b>	[ mg/l ]	10.0	452.0	4.2
<b>NH<sub>4</sub>-N</b>	[ mg/l ]	1.0	73.8	0.4
<b>total nitrogen</b>	[ mg/l ]	12.0		6.8
<b>total phosphorus</b>	[ mg/l ]	1.6	13.4	0.6



## 2.4 Sewage Plant of Dalian, 130,000 PE



**Fig. 9:** Dalian, China: Lineardecanter



**Fig.10:** Dalian, China: in operation



### 2.4.1 Plant Data

Capacity	CWSBR®-plant with 130,000 PE
Begin of operation	Jan. 2008
Daily inflow quantity	30,000 m <sup>3</sup> / d

### 2.4.2 Purification Results

	Unit	Binding Values	Average Inflow Concentration	Average Outflow Concentration
<b>COD</b>	[ mg/l ]	50.0	100 - 400	28
<b>BOD</b>	[ mg/l ]	10.0	60 - 280	6
<b>NH<sub>4</sub>-N</b>	[ mg/l ]	5.0	8 - 13	0.4
<b>total nitrogen</b>	[ mg/l ]	15.0	15 - 30	1.8
<b>total phosphorus</b>	[ mg/l ]	0.5	1.8 - 2.5	0.13



### **3 Conclusion**

CWSBR<sup>®</sup>-technology transforms already existing pond treatment plants into modern SBR-plants. Hydro Sails divide the existing pond into holding, SBR and balancing zone. The new construction of a conventional treatment plant is not necessary and in turn a short reconstruction time and expense saving is achieved. The presented reference for the wastewater treatment plant of Fockenbachtal in Rheinland-Pfalz gives proof of these advantages. Here the expansion from 2,400 PE to 3,200 PE was implemented after only 6 weeks of construction time with the integration of all three existing ponds. With costs of approx. 120 €/PE the complete SBR-treatment technology was implemented, leaving potentials for future expense.

The combination of treatment quality, cost effectiveness and extension possibilities makes CWSBR<sup>®</sup>-technology a sustainable development instrument especially for small and medium sized communities.

Tourism or industrial settlements in a region often make the extension of the wastewater treatment plant necessary. The improved bathing water quality, as an example, results in an increased attractiveness for leisure activities of the region and consequently increased touristic activities. Here, CWSBR<sup>®</sup>-technology helps tackle the rising treatment requirements while keeping the effluent charge low.

CWSBR<sup>®</sup>-technology represents a new generation of pond treatment technology, which is not only an economically simple extension measure but also safely meets the legally binding discharge values.

**4 Reference List**

<b>Name</b>	<b>Location</b>	<b>PE before</b> total number of inhabitants and population equivalent	<b>PE after</b> total number of inhabitants and population equivalent	<b>Capacity increase</b>	<b>Date</b>
Buensdorf	Germany	700	1,200	71 %	Jun. 2001
Usadel	Germany	950	1,400	47 %	Nov. 2003
Fockenbachtal	Germany	2,400	3,200	33 %	Oct. 2004
Kasseburg	Germany	600	900	50 %	Nov. 2005
Guelzow	Germany	2,500	3,000	20 %	Jul. 2006
Krummesse	Germany	4,000	4,800	20 %	Feb. 2007
Kleinrinderfeld	Germany	3,000	3,500	17 %	Jan. 2008
Adlkofen	Germany	2,500	3,000	20 %	May 2008
Nauroth-Moerlen	Germany	1,800	2,400	33 %	Aug. 2008
Dalian	P. R. China	-	130,000	100 %	Jan. 2008
Maasholm	Germany	2,000	2,500	25 %	Oct. 2009
Wudalianchi	P. R. China	-	43,000	100 %	Nov.2009
Xingtai	P.R. China	-	210,000	100 %	Dec. 2009
Bei an	P. R. China	-	120,000	100 %	Jun. 2010
Xiwuzhumuqing	P. R. China	-	43,000	100 %	Sep. 2010
Xingtai	P. R. China	-	210,000	100 %	Sep. 2010
Yingchengzi	P. R. China	-	43,000	100 %	Feb. 2011
Zalaite	P. R. China	-	65,000	100 %	July 2011
Daweiija	P. R. China	-	10,000	100 %	March 2012
Weixia	P. R. China	-	85,000	100 %	Nov. 2012
Grossbellhofen	Germany	1,000	1,400	40 %	April 2014
Alfeld	Germany	1,200	1,600	33 %	Dec. 2014
Dongwugi	P. R. China		150,000	100 %	Mai 2017
Frankenstein	Germany	1,000	1,200	20 %	July 2017
Hunnan	P. R. China	-	350,000	100 %	under const.