Development and Assessment Institute in Waste Water Technology at RWTH Aachen University

Test Report on the Domestic Wastewater Treatment Plant

BIOCLAR

produced by the BIOCLAR company
(BIOCLAR a.s.)

in
82105 Bratislava, the Slovak Republic

Aachen, July 2004

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1 Background of Test Realisation

On grounds of a letter dated 21st June 2002, the Development and Assessment Institute in Waste Water Technology at RWTH Aachen University (PIA) was asked by the company BIOCLAR to conduct a practical testing of a BIOCLAR domestic wastewater treatment plant designed for 8 people according to the European Norm EN 12566, Part 3.
The plant was installed in the test room of PIA on 22nd April 2003 and on 27th September 2003 it was put into operation. Following the start-up phase, the testing began on 4th August 2003 and ended on 18th June 2004.

2 Description of BIOCLAR Domestic Wastewater Treatment Plant

The BIOCLAR company describes the manner of operation of the BIOCLAR plant as follows:

General Description:
The BIOCLAR aerated wastewater treatment plants consist of cylinder-shaped biological reactors made of wastewater-resistant plastic (polypropylene) and they are delivered as finished products including the vessel cover, electric control unit, indicator lights, the sealed engine-hour meter and blower.
The oxygen is supplied by means of pressurization through aeration tubes producing fine bubbles. The plants are designed to work with no moving parts. The compressor is the only machine element of the plant; its task is to ensure ventilation and circulation of sludge inside the plant.

Field of Application:
The BIOCLAR wastewater treatment plants are used for clarifying domestic wastewater before it can be discharged into water bodies.
Harmful substances cannot be discharged into the plant. Rainwater, surface water, drain water, groundwater, cooling water as well as water discharged from swimming and plunge pools (e.g. water used in sauna) cannot be discharged into the plant too. If a huge amount of wastewater of higher-than-average temperature is to be discharged into the plant, it should be ensured that the temperature of the inflowing water is not higher than 35°C. If the wastewater is discharged from catering facilities or canteens, the plant should be equipped with grease separators. Waste vegetable oils and frying oils as well as kitchen waste (even in a small amount) are not allowed to be discharged into the plant.

Mode of Operation:

The plant consists of a bioreactor and a sludge storage tank. The reactor is designed to clarify wastewater and sludge-water mixture; the sludge storage tank provides place for accumulation of surplus sludge discharged from the reactor.

The bioreactor is vertically divided into three functional zones:

- anaerobic fermentation and denitrification zone (AF-D zone)
- aerated nitrification zone (N zone)
- settling zone (S zone)

The wastewater flows into the anaerobic fermentation and denitrification zone which is divided into four chambers. The first chamber ensures the mechanical pre-treatment by means of a removable screen basket which strains out any coarse solids.

The partial stream of the wastewater-sludge mixture is pumped by an airlift pump from the last chamber into the first chamber; in this chamber, the wastewater-sludge is blended with the wastewater. The hydrodynamic effect of the recirculated flow of the activated sludge disintegrates the filtered coarse solids and forces the wastewater-activated sludge mixture to circulate through all chambers of the AF-D zone.

The arrangement of underflow and overflow baffles in the AF-D zone creates an ascending and descending flow, keeps the activated sludge in suspended state and ensures that the content of the AF-D zone is blended continuously. As for the next stage of the treatment, the stream continues to the underflow baffle (through an opening) in the second chamber, then it flows through the overflow baffle in the third chamber and in the fourth chamber again, it flows through the underflow baffle. The total width of the baffle passages is that one of baffle walls and there are no physical constraints.

Then the mixture of wastewater and sludge flows over the overflow barrier of the last chamber into the nitrification zone and there it becomes aerated. This entire process cannot take place if the next inflow of the wastewater into the plant or the outflow of the activated sludge from the settling zone doesn't take place at the same time. Finally, through continuous operation and aeration, nitrification takes place within the N zone. In order to achieve an optimal operation of the plant, the following conditions should be met: MLSS (as measured) in the AF-D zone should range between 7-8 kg/m^3, MLSS measured in the N zone should be in the range of 4-5 kg/m^3; as for MLDO, its value measured in the AF-D zone should be below 0.1 mg/l and in the range of 2-3 mg/l in the N zone.

The wastewater-activated sludge mixture flows through the connecting gap, which is located on the partition wall separating the S and N zone, from the nitrification zone to the settling zone. The suction inlet is located at the bottom of the settling zone and it ensures the recirculation of settled sludge, while the activated sludge is pumped by the airlift pump into the second chamber of the AF-D zone. The settling zone also contains a degassing unit.

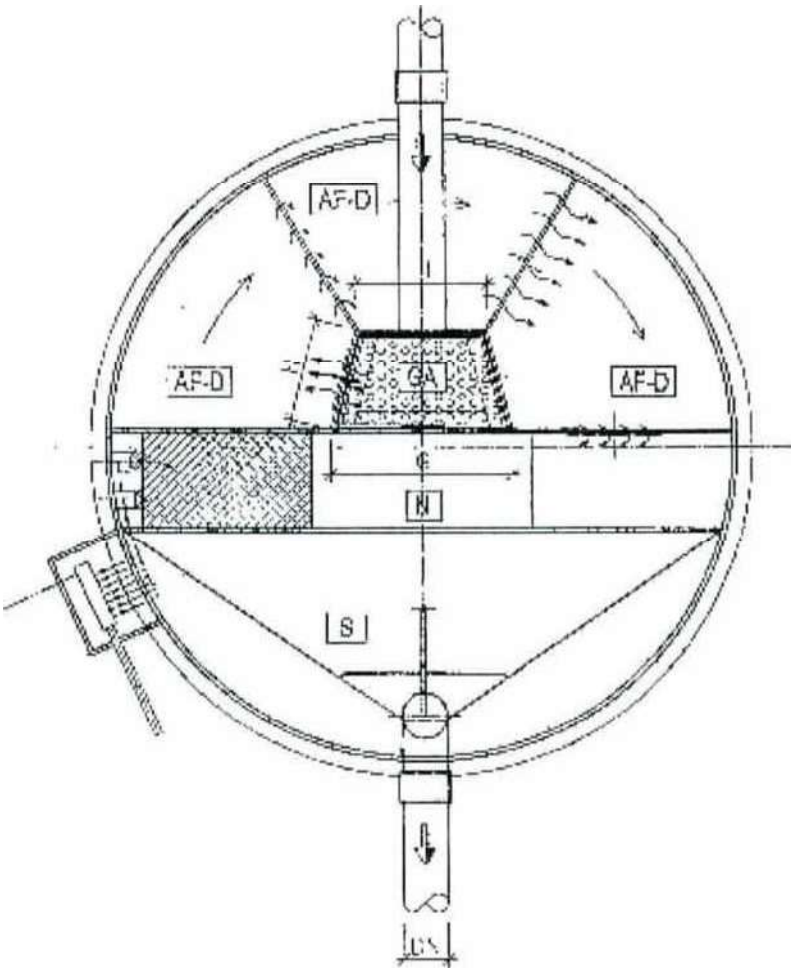


Figure 1: Component drawing of the BIOCLAR plant

2 Sampling Procedure and Analysis

As for the entire sampling process, 24-hours composite samples have been taken from both the inflow and outflow of the plant. The samples have been taken continuously from the water discharged from the plant during a pumping procedure and they have been stored in cooled sampling containers.

All parameters have been laid down by regulations of the respective norm.

During the sampling, the following parameters have been measured:

Inflow: T, pH, total COD, BOD_5, NH_4-N, Total Nitrogen, Total Phosphorus, Conductivity, Filterable Substances (AFS), Sedimentable Substances (AS_{120})

Bioreactor: T, O_2, Sludge Volume (SV_{30}), MLSS, Loss on Ignition (LOI)

Outflow: T, pH, Homogenized COD (CODhom), Filtered Chemical Oxygen Demand (CODfil), BOD_5, NH_4-N, NO_3-N, total N, total P, Conductivity, Filterable Substances (AFS), Sedimentable Substances (AS_{120})

4 Testing Process and its Special Characteristics

The operation of the wastewater treatment plant designed for meeting the needs of 8 people has been computer-controlled in accordance with the EN 12566 norm, Part 3 and the plant has been supplied with 1,200 litres of wastewater per day. Table 1 presents the summary of the process.

Table 1: Stages of the BIOCLAR plant testing

Testing stage	Duration/Date
Start of the testing	4th August 2003
Normal operation	5 weeks
Power outage	2 weeks
Normal operation	16 weeks
150% workload	2 weeks
Normal operation	2 weeks
Holiday	2 weeks
Normal operation	2 weeks
Power outage	2 weeks
Normal operation	6 weeks
50% workload	2 weeks
Normal operation	2 weeks
50% workload	2 weeks
Normal operation	1 week
End of the testing	18th June 2004

During the testing period, the **average electric consumption** amounted **2.97kWh/d**.

Table 2 includes the average run time of the air compressor.

Table 2: Run time of the compressor

	Run time (h/day)
Compressor	20.61

5 Clarification Process

5.1 Results

Table 3 provides average, minimum and maximum values as well as respective standard deviations and other figures and parameters of the plant.

Table 3: Figures and parameters of the plant

	Average	**Minimum**	**Maximum**	**Standard deviation**
Sludge loading (BTS) [kg/kg.d]	0.27	0.01	2.10	0.62
Volumetric loading [kg/m^3.d]	0.11	0.05	0.16	0.03
BOD_5 efficiency [%]	95.59	84.38	99.32	4.49
COD efficiency [%]	89.79	81.82	95.61	4.40
*Total N efficiency [%]	73.61	43.48	93.83	14.78
*NH_4-N efficiency [%]	96.78	93.14	98.98	2.32
*Outflow NH_4-N [mg/l]	1.31	0.40	2.60	0.91
*N_{inorg} outflow [mg/l]	10.63	1.80	25.30	7.12
Outflow total N [mg/l]	14.63	3.70	26	7.13
Outflow total P [mg/l]	3.25	1.10	5.60	1.28
COD outflow [mg/l]	61.75	34	126	28.86
BOD_5 outflow [mg/l]	10.45	2	40	11.66
AFS outflow [mg/l]	18.60	5	53	13.02

*calculated based on results at temperatures > 12°C (activated sludge tank)

The following charts include individual results of all the tested parameters. Values exceeding the threshold value are highlighted in red colour.

Table 4: Results acquired during the testing period 5th August 2003 - 23rd December 2003

PIA – No.:	**KKA 2002-05**					
Company:	**Bioclar**					
Plant type:	Activated sludge tank					
Test stage:	**1 – 3**	**POWER OUTAGE**				
Sampling No.(PN)		PN 1 - 1	PN 1 - 2	PN 2 - 1	PN 2 - 2	PN 3 - 1
Date		05.08.03	20.08.03	09.09.03	12.09.03	23.12.03
Air temp. min/max	[°C]	21/39	14/34	10/20	8/20	2/9
Inflow:						
Temperature	[°C]	21.6	19.9	16.0	17.0	9.9
COD	[mg/l]	576	664	766	341	410
BOD_5	[mg/l]	296	301	254	132	153
NH_4-N	[mg/l]	34	49	36	43	25
Total N	[mg/l]	58	52	60	50	46
Total P	[mg/l]	7.7	9.5	8.8	7.2	6.9
pH	[-]	6.7	7.1	7.4	7.5	7.5
Conductivity	[uS/cm]	842	881	830	851	875
AFS	[mg/l	287	315	557	172	295
AS 120	[ml/l]	35	40	45	25	25
Outflow:						
Temperature	[°C]	20.4	194	15.0	15.8	6.6
CODhom	[mg/l]	35	56	34	40	63
CODfil	[mg/l]	33	54	32	31	46
BOD_5	[mg/l]	2	4	5	3	10
NH_4-N	[mg/l]	0.4	0.5	0.4	0.9	19
NO_3-N	[mg/l]	16	9.8	1.4	2.7	0.3
Ninorg	[mg/l]	16.4	10.3	1.8	3.6	19.3
Total N	[mg/l]	21	15	3.7	6	27
Total P	[mg/l]	2.4	3.5	2.9	2.6	1.1
pH	[-]	7.3	7.3	8	7.5	7.5
Conductivity	[uS/cm]	588	554	544	544	783
AFS	[mg/l]	6	5	6	5	30
AS 120	[ml/l]	< 0.1	< 0.1	0.2	0.1	1.2
Bioreactor:						
Temperature	[°C]	21.9	18.3	14.9	14.5	7.5
SV_{30}	[ml/l]	150	150	150	90	340
MLSS	[g/l]	2.0	1.9	1.7	1.2	4.3
LOI	[%]	79.4	80.3	85.2	78.2	87.9
O_2	[mg/l]	3.9	5.9	4.9	6.1	6.9
Notes:		Suspended materials in outflow	Suspended materials in outflow		Activated sludge in outflow	

Table 5: Results acquired during the testing period 8th January 2004 – 9th March 2004

PIA – No.:	**KKA 2002-05**					
Company:	**Bioclar**					
Plant type:	Activated sludge tank					
Test stage:	**3 – 6**		**150%**	**HOLIDAY**	**HOLIDAY**	**POWER OUTAGE**
Sampling No.(PN)		PN 3 - 2	PN 4 - 1	PN 5 - 1	PN 5 - 2	PN 6 - 1
Date		08.01.04	20.01.04	24.02.04	27.02.04	09.03.04
Air temp. min/max	[°C]	8/9	6/9	-6/7	-9/2	-1/11
Inflow:						
Temperature	[°C]	11.9	9.3	7.9	7.3	7.1
COD	[mg/l]	429	465	601	896	693
BOD_5	[mg/l]	151	112	219	284	269
NH_4-N	[mg/l]	25	34	60	36	37
Total N	[mg/l]	49	48	79	52	52
Total P	[mg/l]	7.5	6.7	10.8	11.5	8.6
pH	[-]	7.6	7.5	8.1	7.6	7.7
Conductivity	[uS/cm]	895	754	845	887	789
AFS	[mg/l	271	390	437	612	518
AS 120	[ml/l]	30	35	25	25	25
Outflow:						
Temperature	[°C]	11.8	9.7	4.3	3.5	6.5
CODhom	[mg/l]	57	47	109	104	126
CODfil	[mg/l]	39	24	84	61	99
BOD_5	[mg/l]	7	5	24	30	35
NH_4-N	[mg/l]	19	22	33	35	31
NO_3-N	[mg/l]	0.3	0.9	0.2	0.1	0.2
Ninorg	[mg/l]	19.3	22.9	33.2	35.1	31.2
Total N	[mg/l]	29	26	37	36	35
Total P	[mg/l]	2.5	2.7	5.2	5.6	1.7
pH	[-]	7.7	7.7	7.8	7.8	7.6
Conductivity	[uS/cm]	760	694	783	917	742
AFS	[mg/l]	27	16	33	36	53
AS 120	[ml/l]	<0.1	1.0	0.3	0.3	1.0
Bioreactor:						
Temperature	[°C]	7.1	6.5	5.2	4.4	6.2
SV_{30}	[ml/l]	130	150	4	4	40
MLSS	[g/l]	1.7	1.7	0.04	0.05	2.0
LOI	[%]	81.6	81.1	87.8	79.1	73.3
O_2	[mg/l]	7.0	7.9	7.5	5.7	7.6
Notes:				NO_2-N. < 0.02		

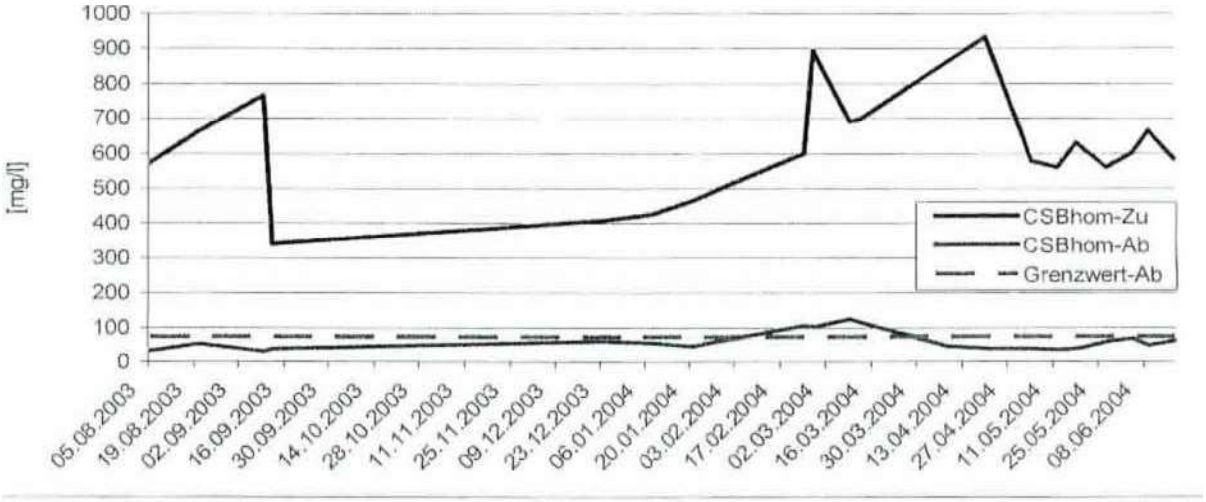
Table 6: Results acquired during the testing period 12th March 2004 – 12th May 2004

PIA – No.:	**KKA 2002-05**					
Company:	**Bioclar**					
Plant type:	Activated sludge tank					
Test stage:	**6 – 8**	**POWER**				**50%**
Sampling No.(PN)		PN 6 - 2	PN 7 - 1	PN 7 - 2	PN 7 - 3	PN 8 - 1
Date		12.03.04	08.04.04	20.04.04	04. 05.04	12.05.04
Air temp. min/max	[°C]	-3/8	4/8	2/20	6/23	8/15
Inflow:						
Temperature	[°C]	6.9	9.1	8.6	12.3	11.8
COD	[mg/l]	699	863	934	579	560
BOD_5	[mg/l]	256	359	281	248	209
NH_4-N	[mg/l]	35	33	46	41	35
Total N	[mg/l]	49	51	71	59	51
Total P	[mg/l]	7.8	11.7	11.6	8.7	11
pH	[-]	8.0	7.3	7.8	7.7	7.5
Conductivity	[uS/cm]	816	720	842	768	970
AFS	[mg/l	273	649	699	389	300
AS 120	[ml/l]	20	47	38	30	25
Outflow:						
Temperature	[°C]	6.6	7.6	9.3	12.9	12.1
CODhom	[mg/l]	117	47	41	41	36
CODfil	[mg/l]	71	32	16	31	23
BOD_5	[mg/l]	40	7	3	3	3
NH_4-N	[mg/l]	30	14	18	0.7	0.7
NO_3-N	[mg/l]	0.2	1.3	1.4	1.4	2.1
Ninorg	[mg/l]	30.2	15.3	19.4	2.1	2.8
Total N	[mg/l]	35	18	23	7.3	19
Total P	[mg/l]	3.7	1.7	2.8	2.1	4.2
pH	[-]	7.7	7.7	7.7	7.4	7.3
Conductivity	[uS/cm]	895	822	666	606	738
AFS	[mg/l]	36	14	13	13	8
AS 120	[ml/l]	0.2	0.9	0.5	0.4	0.1
Bioreactor:						
Temperature	[°C]	5.8	8.3	10.1	13.1	11.7
SV_{30}	[ml/l]	105	40	110	100	130
MLSS	[g/l]	2.2	0.5	1.6	1.0	1.5
LOI	[%]	91.0	80.5	83.8	77.7	78.6
O_2	[mg/l]	7.9	9.2	7.5	5.9	6.4
Notes:						

Table 7: Results acquired during the testing period 18th May 2004 – 17th June 2004

PIA – No.:	**KKA 2002-05**					
Company:	**Bioclar**					
Plant type:	Activated sludge tank					
Test stage:	**9 – 11**			**50%**	**50%**	
Sampling No.(PN)		PN 9 - 1	PN 9 - 2	PN 10 - 1	PN 10 - 2	PN 11 - 1
Date		18.05.04	27.05.04	04.06.04	09.06.04	17.06.04
Air temp. min/max	[°C]	9/21	3/19	11/23	16/28	10/24
Inflow:						
Temperature	[°C]	14.1	11.9	14.8	19.1	15.5
COD	[mg/l]	630	560	602	665	585
BOD_5	[mg/l]	281	276	250	297	249
NH_4-N	[mg/l]	47	42	35	41	43
Total N	[mg/l]	60	62	53	71	46
Total P	[mg/l]	10.0	8.6	7.9	9.6	8.5
pH	[-]	7.6	7.7	7.6	7.6	7.6
Conductivity	[uS/cm]	832	782	736	820	779
AFS	[mg/l	350	300	303	356	290
AS 120	[ml/l]	20	20	20	20	15
Outflow:						
Temperature	[°C]	14 0	11.4	16.1	15.5	12.6
CODhom	[mg/l]	41	60	69	49	63
CODfil	[mg/l]	40	54	53	46	47
BOD_5	[mg/l]	4	6	6	5	7
NH_4-N	[mg/l]	1.5	2.6	2.4	0.8	2.3
NO_3-N	[mg/l]	7.2	4.5	6.3	13	23
Ninorg	[mg/l]	8.7	7.1	8.7	13.8	25.3
Total N	[mg/l]	20	14	11	15	26
Total P	[mg/l]	4.9	3.1	3.4	3.4	5.4
pH	[-]	7.1	7.7	7.6	7.4	7.3
Conductivity	[uS/cm]	570	558	546	540	567
AFS	[mg/l]	11	11	17	15	17
AS 120	[ml/l]	<0.1	< 0.1	<0.1	< 0.1	0.3
Bioreactor:						
Temperature	[°C]	13.1	12.7	14.4	16.8	15.8
SV_{30}	[ml/l]	110	95	100	75	100
MLSS	[g/l]	1.7	0.7	0.9	1.2	1.6
LOI	[%]	76.5	84.1	72.9	74.2	72.3
O_2	[mg/l]	1.9	6.2	8.3	6.0	6.2
Notes:						

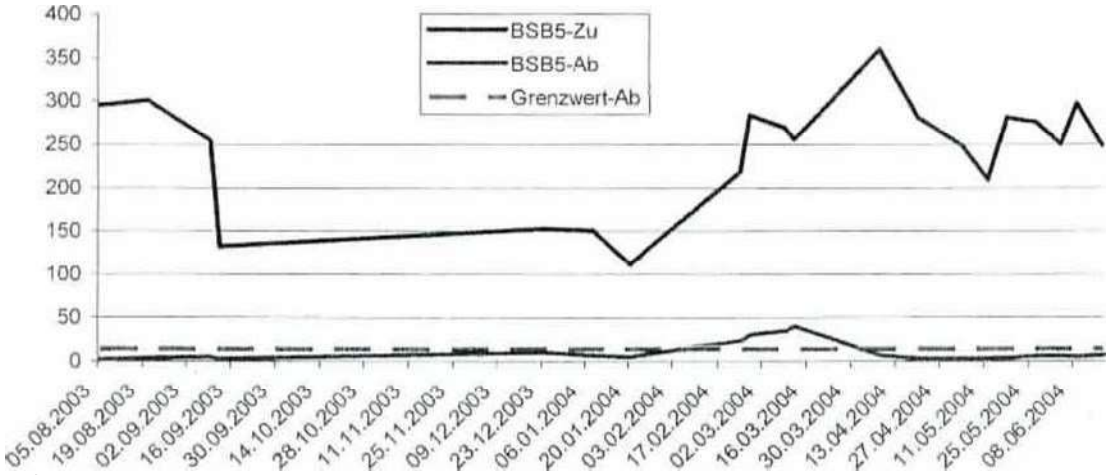
In order to stress the test results, the following charts depicting various tested parameters have been made.



Legend:
Inflow CODhom
Outflow CODhom
Outflow Threshold

Figure 2: Concentration values of COD in the inflow and outflow of the plant

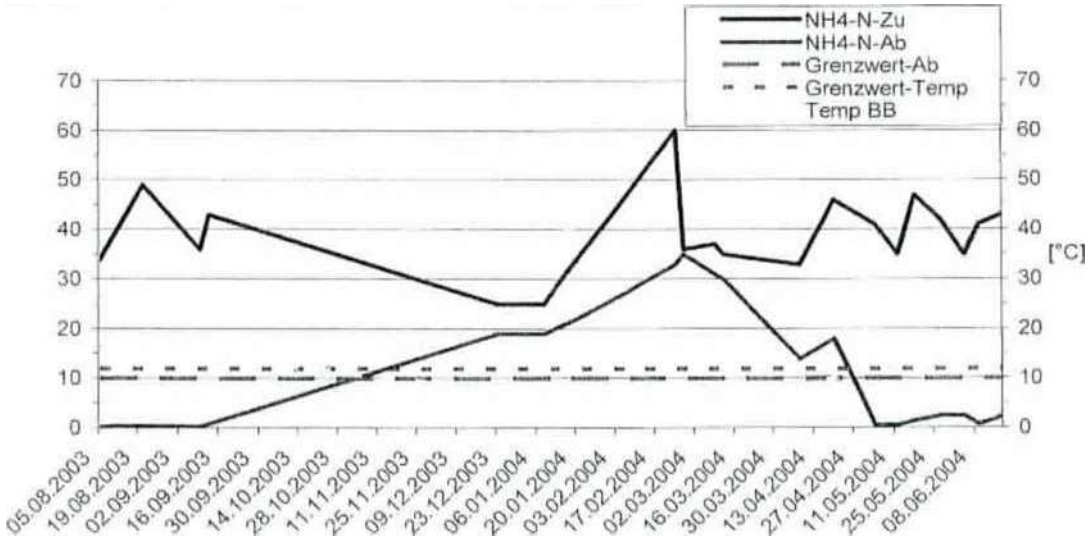
During the entire testing period, the threshold value of 75 mg/l COD has been exceeded four times (twice after the holiday period in February 2004 and twice following the power outage in March 2004).



Legend:
Inflow BOD_5
Outflow BOD_5
Outflow Threshold

Figure 3: Concentration values of BOD_5 in the inflow and outflow of the plant

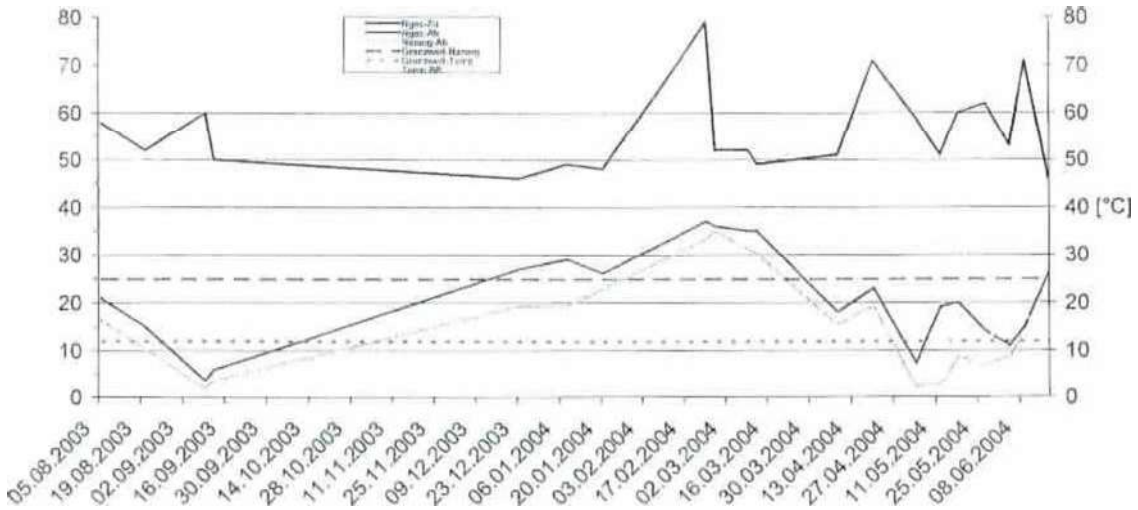
During the entire testing period, the threshold value of 15 mg/l BOD_5 has been exceeded three times – once after the holiday period in February 2004 and twice after the power outage in March 2004.



Legend:
Inflow NH_4-N
Outflow NH_4-N
Outflow Threshold
Outflow Temperature
BB Temperature

Figure 4: Concentration values of NH_4-N in the inflow and outflow of the plant

The values at the temperature higher than 12°C have crossed the threshold line of 10 mg/l NH_4-N continuously.



Legend:
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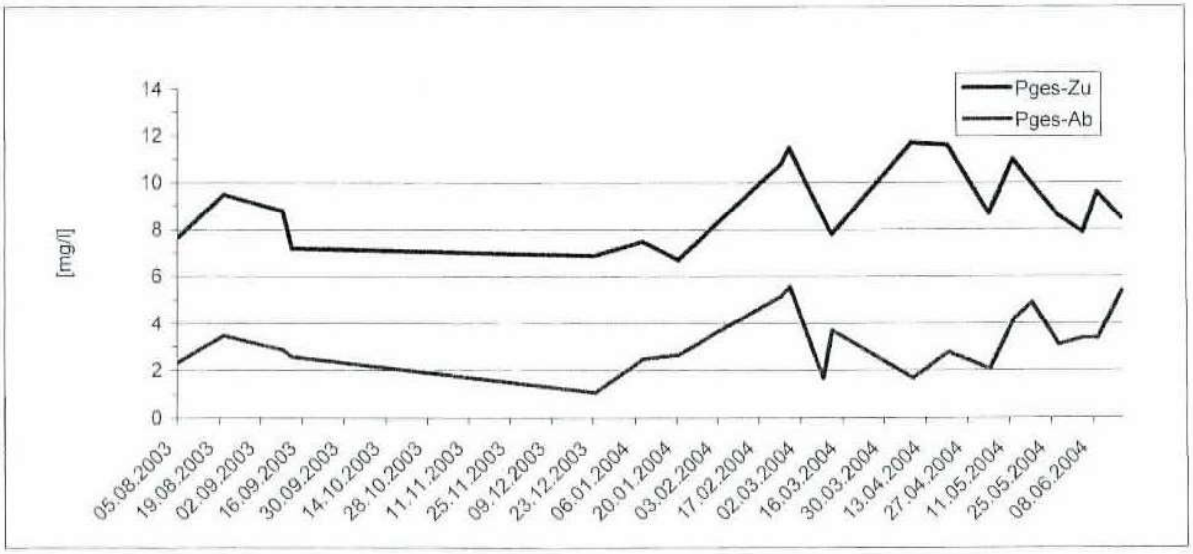
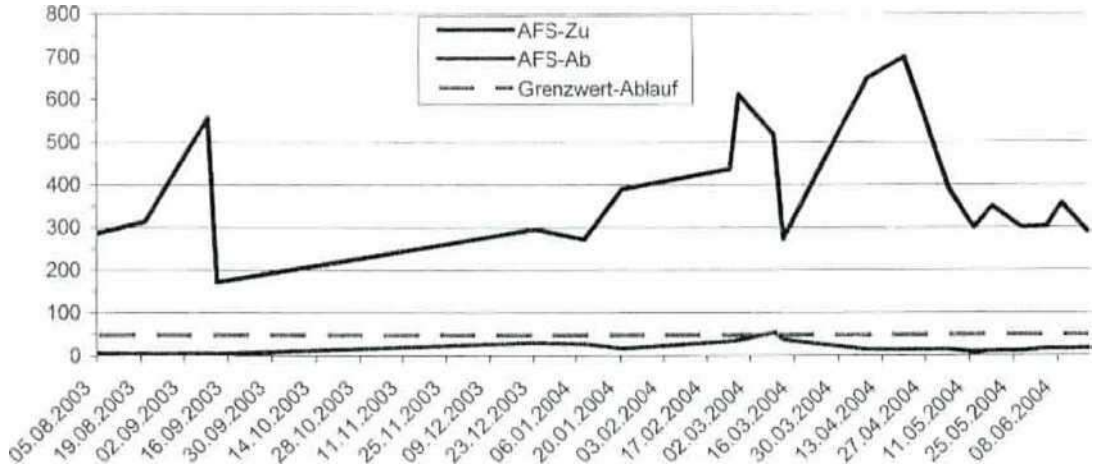
Figure 5: Concentration values of total N in the inflow and outflow of the plant as well as Ninorg values in outflow of the plant with respective threshold line

The values bound to the temperature higher than 12°C have crossed the threshold line of 25 mg/l Ninorg continuously.



Legend:
Inflow Total P
Outflow Total P

Figure 6: Concentration values of Total P in the inflow and outflow



Legend:
Inflow AFS
Outflow AFS
Threshold line

Figure 7: Concentration values of AFS in the inflow and outflow

During the testing period, the threshold value of 50 mg/l AFS has been exceeded once, that is, after the power outage in March 2004.

5.2 Adaptation to Changing Biological Situations

According to the results as shown in figures 2-7, the domestic wastewater treatment plant produced by BIOCLAR managed to adapt to different load situations.

The required bathtub test results are presented in the following chart.

(Missing data will be provided later)

Table 8: Bathtub test results

Parameter	Dim	0 min	1 min	2 min	3 min	4 min
COD	mg/l	108	117	135	121	94
BOD_5	mg/l					
AFS	mg/l					

6 Operational Safety Assessment

6.1 Operational Safety of Electro-mechanical Components of the Plant

During the whole testing period, no electronic or mechanic flaws or defects have been detected.

6.2 Operation and Operational Safety of Secondary Sludge Drainage

The secondary sludge has been drained off by means of an airlift pump into the separate sludge storage tank, the duration of the pumping being 5 minutes per week. The remaining wastewater could flow back into the N zone of the plant. In order to support sludge thickening and blend its content, the storage tank contains a tube aerator. The proper drainage of sludge from the sludge tank cannot be guaranteed if the compressor doesn't work flawlessly. Therefore, the regular maintenance of the compressor should be of high importance.

6.3 Sludge Removal and Sludge Sediment Control

If the maintenance and checking of the screen basket is done properly and regularly, there shouldn't be any sludge sediments.
The amount of sludge in the storage tank was checked on the 17th June 2004 and revealed the sludge level of 0.7 m.

7 Effects on Surroundings

The wastewater treatment plant has produced neither noise pollution nor odor nuisance.

8 Accessibility of Plant Parts

The plant is delivered with a two-piece cover that covers the entire diameter of the plant.
All plant parts are accessible.
The accident prevention regulations shall be applied and followed.

9 Amount of Maintenance and Checks Required

The plant requires the amount of maintenance and checks that is equivalent to that of a standard domestic wastewater treatment plant. The BIOCLAR employees have conducted the maintenance of the plant three times during the entire testing period.
The plant is equipped with a visual fault indicator.

10 Summary and Conclusion

The Development and Assessment Institute in Waste Water Technology at RWTH Aachen University (PIA) has conducted a practical testing of the BIOCLAR wastewater treatment plant in accordance with the European Norm EN 12566, Part 3. The plant was installed in the test room of the institute.
During the testing period no electronic or mechanic flaws or defects occurred.
The following average concentration values of 24-hour composite samplings from the plant outfall have been calculated:

- COD: 61.8 mg/l
- BOD_5: 10.5 mg/l
- NH_4-N: 1.3 mg/l
- N_{inorg}: 10.6 mg/l
- AFS: 18.6 mg/l

The average values concerning the efficiency of the clarification process are as follows: 89.8% efficiency of COD, 95.6% BOD_5, 96.8% NH_4-N and 73.6% for Total N.

The plant has produced neither noise pollution nor odor nuisance. All plant parts and components were easily accessible.

The domestic wastewater treatment plant produced by BIOCLAR is well-suited for use as a wastewater treatment plant capable of nitrogen removal.

11 Annex

The basis data for assessment of the plant (exemplary for the wastewater treatment plant of the B10 type designed for 8 residents):

Amount of wastewater:

Amount of wastewater	150 l/person *d
Inflow of wastewater per hour	1/10 of the daily amount
Daily load of wastewater	1.2 m^3/d
Max wastewater inflow per hour	0.12 m^3/d

Wastewater pollution:	60 g BOD_5/person*d
	12 g Total N/person*d

Plant parameters and assessment:

Activated sludge tank

Required volumetric loading	0.2 kg BOD_5/m^3*d
BOD_5 loading	0.48 kg BOD_5/d
Required volume	2.4 m^3
Actual volume of tank	2.7 m^3
Actual volume of AF-D zone	1.3 m^3
Actual volume of N zone	1.4 m^3

Air supply system

Special oxygen consumption	3.0 kg O_2/kg BOD_5
Required daily amount of oxygen	1.44 kg/d
Oxygen input per m of Blow In Depth	18.0 g O_2/m^3 air/m
Blow In Depth	1.26 m
Oxygen input at Blow in Depth	23 g O_2/ m^3 air
Oxygen transfer (Alpha factor)	0.7
Required daily amount of air	91 m^3 air/d
Aeration period per day	16 h
Required blower performance	5.0 m^3/h
Actual blower performance	5.7 m^3/h
Blower power	100 W
Electricity consumption per year	584 kWh/a
Fine bubble membrane diffuser	2.5 m^3 air/linear meter*d
Membrane diffuser total length	2.0 linear meter

Settling zone

Max wastewater inflow per hour	0.12 m^3/h
Required surface flow rate	0.3 m^3/m^2 *h
Required settling surface area	0.4 m^2
Minimum settling surface area	0.7 m^2
Available settling surface area	0.71 m^2
Actual surface flow rate	0.17 m^3/m^2*h
Settling zone volume	0.4 m^3
Required retention time	3.0 h
Actual retention time	3.3 h

Sludge storage tank

Required storage volume	1.2 m^3
Actual storage volume	2.0 m^3