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Report on the measurements of the INP within the installation of a plasma-based reactor for odour removal at water treatment plants

Analysis by FTIR, electrochemical sensors and chemical analytics by Helge Grosch and Ronny Brandenburg

The following report discusses the results of the measurements taken at the waste water treatment plants (WWTP) of Aquanet in Poznań (ul. Serbska 3) and in Kozięgłowy (ul. Gdanska 1). The scope of these measurements was, to identify the main chemical agents in the off gas of the WWTP before and after plasma-catalytic treatment at three different test sites. The following report is structured as follows: First an introduction into the different measurement, their advantages and disadvantages, is given. Afterwards the results are listed and a short conclusion is provided.

The measurements with the FTIR in Poznań have been carried out at the same time as the samples for the olfactometry were taken. In the case of the two test sites in Kozięgłowy, the measurements with the FTIR have been carried out with the same samples of the olfactometry. Since for each test site the results look very similar, we will show exemplary results and discuss the differences to previous measurements.

1. Introduction in the methods of measurement

Three different types of diagnostic methods were used for the detection of the appearing species. For a general approach, the detection of the main species, the method of FTIR spectroscopy was used. For the detection of trace gases, gas chromatography coupled with mass spectroscopy (GC/MS) was used. Therefore, adsorption tubes were rinsed with the exhaust gas before and after plasma section and analysed by GC/MS afterwards. The third method was the electrochemical sensing of H_2S by a handheld device.

FTIR spectroscopy:

The fourier transform infrared spectroscopy (FTIR) is a low invasive procedure for the detection of species in mixtures. The basic of this technology is the absorption of light by the sample. A light source emits a certain spectrum of light, which is directed through a chamber including the sample. In this chamber, the light is partly absorbed. A detector then records the transmitted light. By comparing the transmitted light at the different wavelength of the sample and the background spectrum, a transmission spectrum can be given. Since every chemical agent has different absorption behaviour, the single agents can be identified.





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Since the FTIR deals with infrared light, all detectable species must be infrared active. This is not the case with biatomic homonuclear molecules (e.g. N_2 and O_2) and atomic radicals (O and N). Other drawbacks are the difference in detection limit of odours by FTIR and human noses at reasonable efforts (the detection limit of the FTIR can be too high to detect these) and the similarity in the spectrum of different agents (similar chemicals sometimes can not be detected) as well as the vanishing of low spectra in always appearing spectra such as CO_2 and water.

In the used configuration, the FTIR was applied to the mixture of off gases from the WWTP. The measurements were conducted before and after the treatment of the off gas by the plasma-catalyst reactor chamber. The used FTIR spectroscope was the device "alpha" by Bruker equipped with a 4.8 m heatable long path gas cell.

GC/MS:

In gas chromatography (GC) the compounds are separate based primarily on their volatilities. Therefore, a carrier gas with the compounds (which are desorbed of the adsorption material by thermodesorption in the test tubes) moves through a GC column. The compounds partition between a stationary phase (column inner wall) and a mobile phase (gas). The differential partitioning into the stationary phase allows the compounds to be separated in time and space, while the retention time of the compounds is known. After separation the compounds are detected by a mass spectrometer (MS). As adsorption medium Tenax tubes were used. The GC was the "GC 2010 with TD-20 and QP 2010" of Shimadzu and the column "Phenomenex ZB-5" was used. Their specifications can be found in the appendix.

The task of the GC/MS was to detect chemical agents present in the off gas, but below the detection limit of the FTIR as well as an identification of produced and reduced agents at the inlet and outlet of the plasma reactor. Hereby, the main scope was the detection of compounds including sulfur (e.g. mercaptanes, sulfides etc.) due to the fact, that these compounds are known to be strong and unpleasant odours. GC/MS analysis was performed by the laboratory "IUL Vorpommern" in Greifswald as subcontractor of the INP.

Handheld device for H_2S measurements:

With courtesies of "IUL Vorpommern", the H_2S measurements were conducted by means of the electrochemical handheld device "GasAlertMicro 5 IR" with an integrated IR sensor for the CO_2 monitoring. This device has an electrochemical sensor, which was produced for measurements in plants such as the WWTP. The use of this device was necessary, since H_2S cannot be detected by the previous discussed methods and it is known to be a chemical agent with a strong, unpleasant scent.

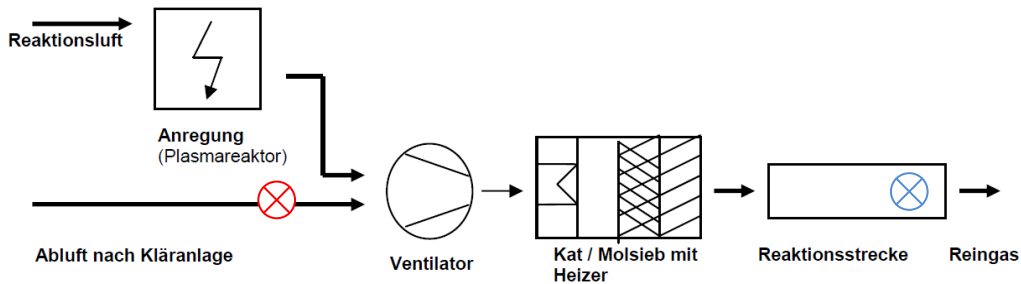




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2. System Envisolve



Measuring points Inlet, Outlet) for FTIR, GC/MS and H₂S; identical with olfactometric sampling; some experiments with scrubber bevor measuring point inleiteinige Versuche mit Wäscher vor Messpunkt Inlet

3. Results for the test site 1 (Poznan, ul Serbska 3):

FTIR spectroscopy:

Due to the fact, that the spectra of the different measurements do not show new species and that quantification can also not be given due to the lack of calibration, only three exemplary spectra are presented.

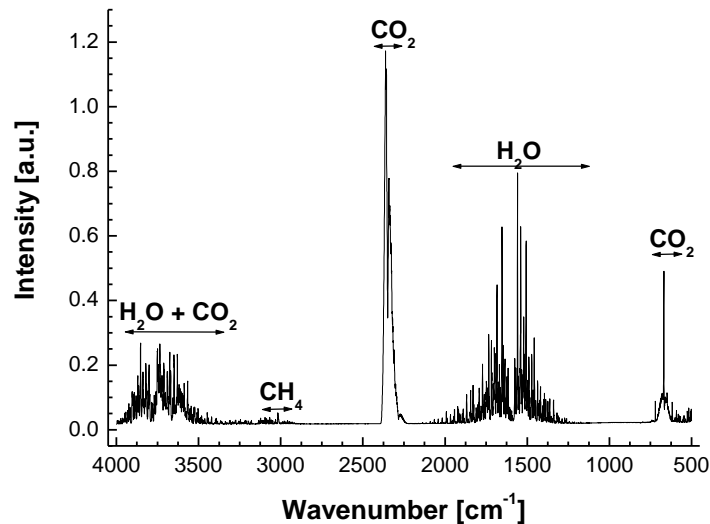


Fig. 1: Spectrum at the inlet (32 scans, 1 cm⁻¹ resolution) for configuration 2 (27.7 °C and 32.4 % relative humidity)



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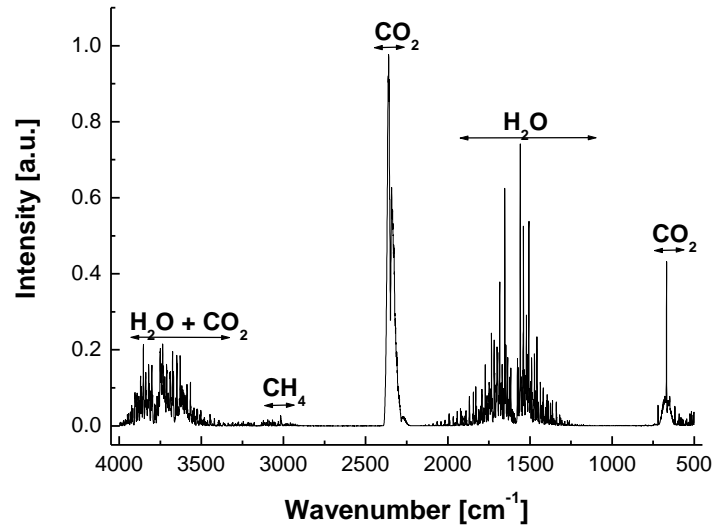


Fig. 2: Spectrum at the outlet (32 scans, 1 cm^{-1} resolution) for configuration 2 (11.8 °C and 75.2 % relative humidity)

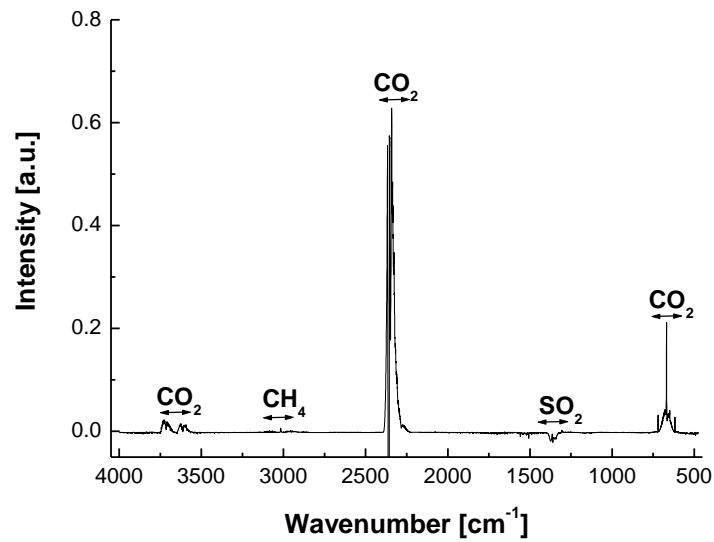


Fig. 3: Outlet spectrum subtracted of the inlet spectrum (32 scans, 1 cm^{-1} resolution) for configuration 4. Negative peaks show the production of species in the reactor (lower concentration at the inlet), positive peaks show species with larger concentration at the inlet.



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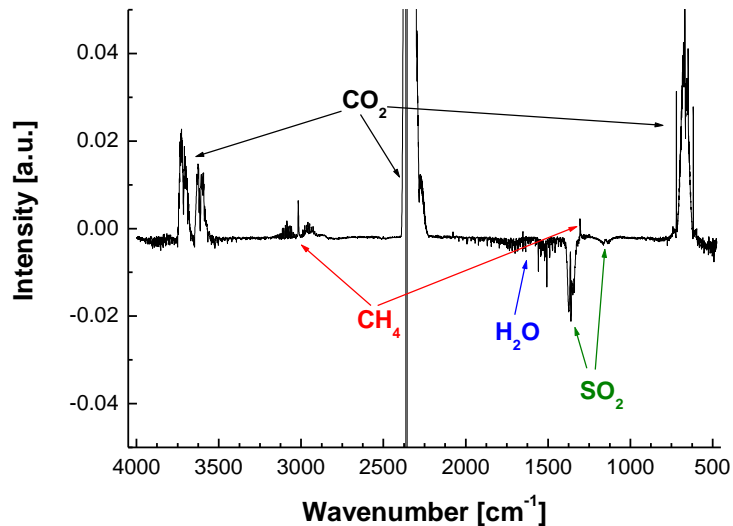


Fig. 4: Detailed view on the spectra in Fig. 3.

From these data, two main results can be concluded. The main species in the off gas are, next to not detectable, N_2 and O_2 , CO_2 and H_2O (see Fig 1. and 2). Their actual values were determined by the handheld device for H_2S measurements and by the humidity probe applied at the inlet and outlet (see below). These species overrule the measurements by their intensity and therefore make a detection of other species difficult. As a second result, two previously unexpected species could be identified in CH_4 (visible in all spectra Fig. 1- Fig. 4) and SO_2 (see Fig. 4). Since in Fig. 4 the difference between the in- and outlet of the plasma reactor and catalyst arrangement are shown, one can determine which chemical agents increase and which decrease easily. Next to CO_2 also CH_4 has a higher inlet concentration. H_2O and SO_2 nevertheless have a higher output concentration. Still one has to keep in mind, that a certain degree of fresh air (10% according to Rafflenbeul Ingenieure) is added during the cleaning process.

GC/MS:

During each measuring campaign, two samples at the inlet and two samples at the outlet were taken. This was due to the fact, that the measurements were time- and cost-intensive. It was meant mainly to identify the basic chemical agents and to see an increase or decrease in their concentration. Here, only the main agents should be named and discussed. A detailed view over all found compounds can be seen in the appendix. The main trace gas components can be seen in Table 1:





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Table 1: Main trace gas components in the different configurations.

	Inlet 10. Feb. 11 Config. 2 [$\mu\text{g}/\text{m}^3$]	Outlet 10. Feb. 11 Config. 2 [$\mu\text{g}/\text{m}^3$]	Inlet 11. Feb. 11 Config. 3 [$\mu\text{g}/\text{m}^3$]	Outlet 11. Feb. 11 Config. 3 [$\mu\text{g}/\text{m}^3$]	Inlet 16. & 17. Feb. 11 Config. 4 [$\mu\text{g}/\text{m}^3$]	Outlet 16. & 17. Feb. 11 Config. 4 [$\mu\text{g}/\text{m}^3$]
Dimethyl sulfide	104.6	93.0	52.8	70.1	117.5 139.2	85.9 79.8
Carbon disulfide	6.4	9.4	0	2.8	42.3 34.2	86.7 106.5
Dimethyl disulfide	667.1	440.5	544.4	307.5	1346.5 1385.2	554.4 454.6
Toluene	65.1	89.1	45.7	78.2	689.3 378.0	288.1 272.1
Dimethyl trisulfide	56.1	338.4	128.2	157.4	354.0 251.2	105.5 80.0

These results show that the main components, next to the agents identified by the FTIR, are sulfur containing agents and toluene. In all samples taken the inlet dimethyl disulfide had the highest value. It was also the component with the best reduction rate. The configuration 2 showed a slight decrease in concentration for dimethyl sulfide, while all other components increased in configuration 2 and 3. The measurements at configuration 4 showed that all main components, except of carbon disulfide decreased. The reduction rate ranged between 26.8 % (dimethyl sulfide) and 70.2 % (dimethyl trisulfide). Nevertheless, next to the composition of SO_2 as stated above, also carbon disulfide (CS_2) was produced during the process. CS_2 is not known for an unpleasant scent.

Table 2 shows the chemical agents which were produced or reduced in significant height in single experiments.

These components are mentioned for the sake of completeness. In the configuration 4 it can be seen that also as pleasant scented known agents, such as limonene, are significantly reduced.

In table 3 the low concentrated sulfur containing gases is shown.





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Table 2: Gases that appeared in some test with significant value.

	Inlet 10. Feb. 11 Config. 2 [$\mu\text{g}/\text{m}^3$]	Outlet 10. Feb. 11 Config. 2 [$\mu\text{g}/\text{m}^3$]	Inlet 11. Feb. 11 Config. 3 [$\mu\text{g}/\text{m}^3$]	Outlet 11. Feb.11 Config. 3 [$\mu\text{g}/\text{m}^3$]	Inlet 16. & 17. Feb. 11 Config. 4 [$\mu\text{g}/\text{m}^3$]	Outlet 16. & 17. Feb. 11 Config. 4 [$\mu\text{g}/\text{m}^3$]
Ethanol	4.5	4.3	<1	111.1	3.0 8.1	2.0 <1
Ethyl- acetate	-	-	<1	146.9	- -	- -
Isopropyl- acetone	<1	34.2	0.9	63.2	- -	- -
Limonene	143.8	136.2	44.7	51.8	46.0 73.8	11.4 6.3
Acetic acid	-	-	-	-	26.8 21.8	84.2 26.3

Table 3: Other detectable sulfur containing gases with unpleasant scent.

	Inlet 10. Feb. 11 Config. 2 [$\mu\text{g}/\text{m}^3$]	Outlet 10. Feb. 11 Config. 2 [$\mu\text{g}/\text{m}^3$]	Inlet 11. Feb. 11 Config. 3 [$\mu\text{g}/\text{m}^3$]	Outlet 11. Feb.11 Config. 3 [$\mu\text{g}/\text{m}^3$]	Inlet 16. & 17. Feb. 11 Config. 4 [$\mu\text{g}/\text{m}^3$]	Outlet 16. & 17. Feb. 11 Config. 4 [$\mu\text{g}/\text{m}^3$]
Disulfide, methyl 2- propenyl	3.1	1.6	1.3	0.5	15.1 21.7	4.8 5.1
Dimethyl tetra- sulfide	2.0	19.6	5.1	19.1	11.5 8.1	3.6 2.3

The treatment of these components shows a similar effect as the treatment of sulfur containing agents with higher concentration. In the configuration 2 and 3, a non-uniform behaviour can be seen. For configuration 4 a significant decrease can be reported.

Against all expectation, only the methanethiol, a mercaptane (which are known for their unpleasant scent), could be detected. With $8.7 \mu\text{g}/\text{m}^3$ at the inlet, its value was relatively small. At the outlet none of this compound could be detected. The detection limit was below $10 \mu\text{g}/\text{m}^3$ (2-methyl-2-propanthiol) respectively $1 \mu\text{g}/\text{m}^3$ (Ethanthiol, 2-Propanthiol, 1-Propanthiol, Tetrahydrothiophen). These limits are in the range of the odour thresholds of these chemical agents. Mercaptanes are volatile compounds. Due to the relative long time between taking the sample and analysis (because of the transport from Poznan to Greifswald), it is possible that the measurement was influenced and that the gas contained actually more mercaptanes.

Handheld device for H₂S measurements:

The measurements for the H₂S detection were carried out at the same time as the olfactometric samples were taken. Therefore, they can be compared directly.

The data show that there is a constant reduction of H₂S by the reactor arrangement. It has to be mentioned that the inlet concentration of H₂S varied significantly. At the time of main emission (measured at 17:00) H₂S values of 21 ppm before (CO₂ at 0.13 %) and 4 ppm after the treatment (CO₂ at 0.12%) could be detected. It is



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also significant, that the rate of CO₂ inlet also increases at the same time as the H₂S value. Furthermore, it has to be mentioned that the reduction rates of 100% are not too trustworthy, since the detection limit was reached.

Table 4: H₂S and CO₂ concentration at the in and outlet measured at the time of olfactometric sample taking for 4 different configurations (10.).

	Date	Time	H ₂ S (inlet) [ppm]	H ₂ S (outlet) [ppm]	H ₂ S reduction [%]	CO ₂ (inlet) [%]	CO ₂ (outlet) [%]
Config.1 (2.4)	10. Feb. 11	10:30	6 ppm	0 ppm	100	0.06 %	0.06 %
Config. 2 (2.5)	10. Feb. 11	13:15	4 ppm	0 ppm	100	0.06 %	0.06 %
Config. 3 (2.6)	11. Feb. 11	8:45	18 ppm	9 ppm	50	0.11 %	0.10 %
Config. 4	-	-	-	-	-	-	-

A measurement at the configuration 4 has not been conducted. Since the fourth configuration was the most promising in the odour reduction, it has also been used in the measurements taken a week later (see: Table 2)

Table 5: H₂S and CO₂ concentration at the in- and outlet measured at the time of olfactometric sample taking for the final arrangement.

See Tab. 17	Date	Time	H ₂ S (inlet) [ppm]	H ₂ S (outlet) [ppm]	H ₂ S reduction [%]	CO ₂ (inlet) [%]	CO ₂ (outlet) [%]
Meas. 1	16. Feb. 11	16:45	10	0	100	0.05	0.07
Meas. 2	16. Feb. 11	19:00	34	7	79.4	0.12	0.13
Meas. 3	17. Feb. 11	15:30	43	13	68.8	0.16	0.12
Meas. 4	17. Feb. 11	17:00	46	12	73.9	0.20	0.15
Meas. 5	17. Feb. 11	19:00	24	6	75.0	0.12	0.12
Meas. 6	17. Feb. 11	20:00	30	4	86.7	0.15	0.11
Meas. 7	18. Feb. 11	11:45	41	6	85.4	0.20	0.15
Meas. 8	18. Feb. 11	13:15	29	5	82.8	0.15	0.17
Meas. 9	18. Feb. 11	14:30	12	4	66.7	0.20	0.11

In general, the inlet value of H₂S was significantly higher than at the testing of the different configurations a week earlier. It ranged from 10 ppm up to 46 ppm. Therefore, the results of the reduction are more comparable. The reduction of H₂S ranges between 100 % and 66.7 % with a mean value of 79.9 %.

Conclusion for the test site 1:

Plasma-catalytic process removes 66 % to 100 % of H₂S, which is probably the main odour. CH₄ emission is reduced as well but not completely. By-product of H₂S removal is SO₂ in small concentrations (can not be quantified since a calibration of the FTIR is missing). This has to be attended since in combination with water H₂SO₄ can be formed, which can affect the plasma catalyst section. Beside H₂S a number of other compounds were detected by GC analytics. Only for configuration 3 an overall statement on the effect of the after





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treatment can be given: All sulfur containing compounds exception for CS_2 decrease in concentration. In the other configurations, some compounds increase in concentration, some decrease. However, since there are no data measured after the plasma section (i.e. before the catalyst), the role of the plasma process cannot be evaluated. But from the viewpoint of these results it can be concluded that the plasma-based treatment and/or the catalyst in use are a promising method for the odour reduction at the water plant in Poznan.

4. Results for the test site 2 (thermal dryer in Kozięglowy):

FTIR measurements:

From these results it can be concluded for the thermal dryer, that next to the already known species carbon dioxide (CO_2), methane (CH_4) and water (H_2O), at a low concentration carbon monoxide (CO) and carbonyl sulfide (COS) can be found in reasonable amounts. Contrary to the other mentioned species, COS is a strong smelling agent.

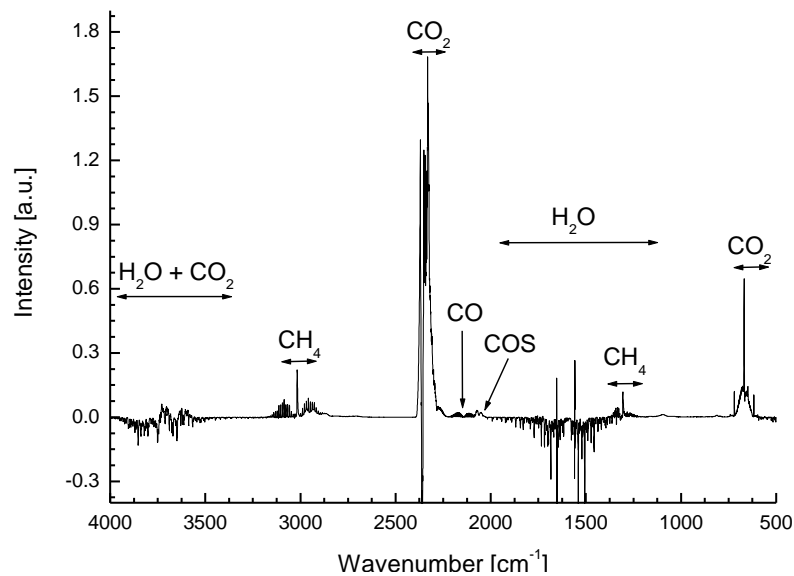


Fig. 5: Inlet to the plasma stage (310W/108°C) after thermal dryer (experiment #7, June 17th 2011).



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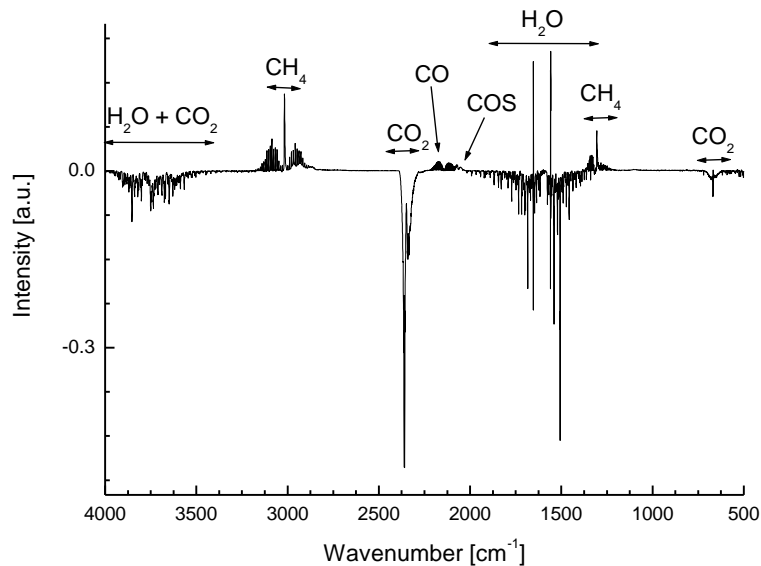


Fig. 6: Outlet to the plasma stage (310W/108°C) minus air sample for exhaust after thermal dryer (Experiment #7 June, 17th 2011).

As a second conclusion, it can be said for sure, that the reduction of COS is influenced mainly by the temperature of the catalyst. A higher catalyst temperature results in a higher decrease of COS. Even though a decrease of COS could also be found after the plasma stage, it is not significantly influenced by the plasma power. In this matter, one has to keep in mind that this result might be due to the admixture of fresh air at the plasma stage.

We also have to note here, that the difference in the spectra before and after the biofilter is negligible. Nevertheless, this means only, that one smelling agent, carbonyl sulfide, is not destroyed in the biofilter.



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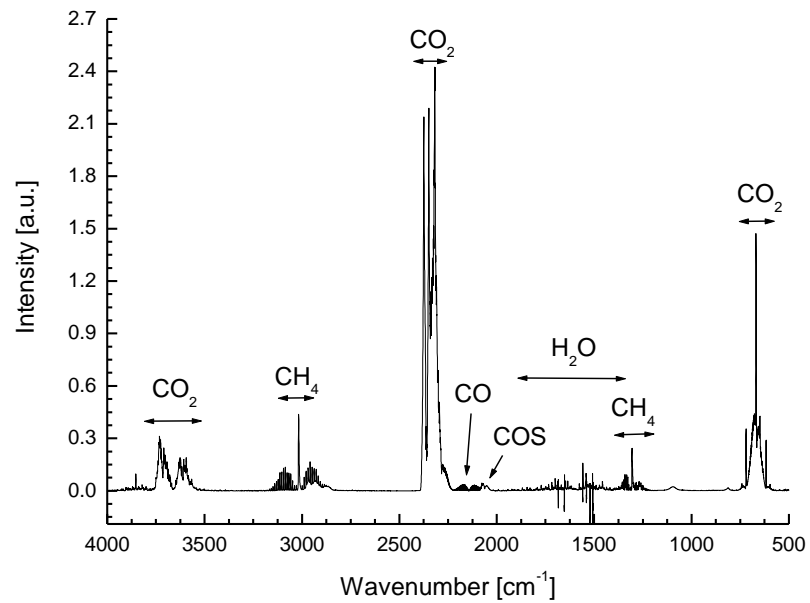


Fig. 7: Inlet to the plasma stage (500W/240°C) after thermal dryer and biofilter (Experiment #11 June 29th 2011).

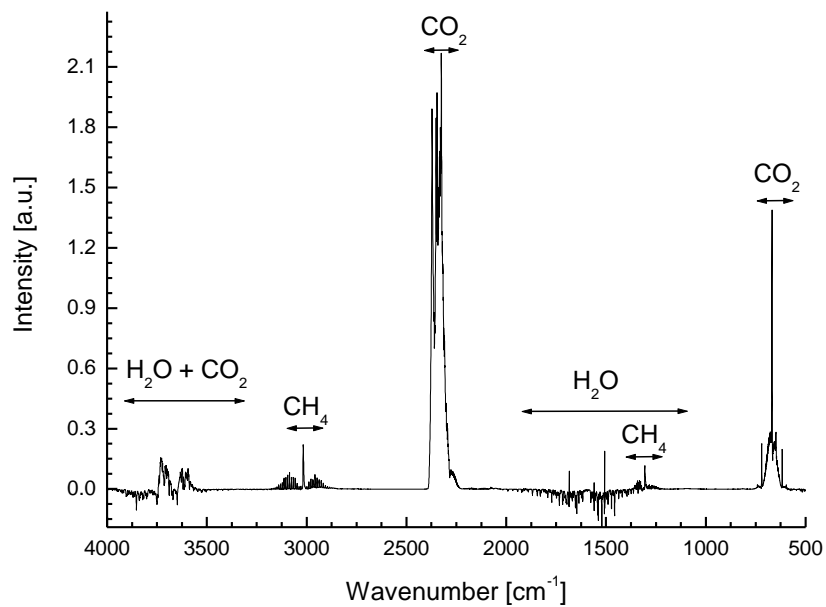


Fig. 8: Outlet of the plasma stage and the catalyst (500W/240°C) after thermal dryer and biofilter (Experiment #11, June 29th 2011).





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GC/MS measurements:

The samples were taken at four different positions, one sample before and after the combination of scrubber, plasma and catalyst, but without biofilter (experiment #9 500W/107°C). Three samples were taken after the biofilter and without scrubber (experiment # 11 500W/240°C, #12 310W/108°C and #13 500W/107°C).

At the given position, the following chemical agents are included at a significant level:

Table 6: chemical agents identified by GC MS at experiment #9 (June 17th, 2011)

	#9 500W/107°C without biofilter		
	Before	After	Reduction rate
	[$\mu\text{g}/\text{m}^3$]	[$\mu\text{g}/\text{m}^3$]	%
Methylbutanal	400	29	93
Aceton	655	238	64
Dimethyl sulfide	129	-	100
Carbon disulfide	675	201	70
Isobutyraldehyde	1160	199	83
2-Methylfuran	144	-	100
3-Methylbutanal	1327	616	53
n-Butanol	1087	593	45
Dimethyl disulfide	433	121	72
Benzyl alcohol	101	-	100
			Build-up rate
			%
Butanone (MEK)	135	172	27
Isobutanale	-	199	100
Methylcyclo- pentane	-	94	100
2-Methylbutanole	-	212	100

These results show that the major components are aldehydes and sulfides. It is known that aldehydes as well as sulfides have a typical smell at low concentrations. Nevertheless, all agents that are detectable at a reasonable concentration (above $100 \mu\text{g}/\text{m}^3$) are reduced except butanone.

As shown in Table 7, before and after the biofilter different agents can be identified than before the biofilter. In general, less aldehydes and more sulfur containing agents are detectable. The concentration of the aldehydes after the biofilter is much lower than before. The difference in concentration of sulfur containing agents, which are mainly responsible for bad smell (see previous reports), is difficult to explain, since more than one week passed between experiment #9 and experiment #11-13.





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Comparing the different experiments (#11-13) with another and the results of olfactometry, one gets contradictory results. The reduction rates of experiment #12 seem to be extremely good. Taking into account, that the odour reduction of approx. 79% was the lowest of the three results, it suggests itself that this sample was somehow corrupted. Anyhow, in experiment #11 and #13, the reduction rates were very similar. Most sulfur containing agents and VOCs were reduced by 6% to 100%. Only toluene was not reduced in both cases. These results suggest that the assumption of sulfur containing agents being responsible for bad smell is right. Since there are a lot of different chemical agents in the off gas (up to 92), it is not possible to say which specific agent of the "cocktail" is mainly responsible. All data can be seen in the appendix.

Table 7: Chemical agents identified by GC MS at experiment #11, #12 and #13 (June 29th, 2011).

	#11 500W/240°C w/o biofilter			#12 310W/108°C w/o biofilter			#13 500W/107°C w/o biofilter		
	Before	After	Red. rate	Before	After	Red. rate	Before	After	Red. rate
	[µg/m ³]	[µg/m ³]	%	[µg/m ³]	[µg/m ³]	%	[µg/m ³]	[µg/m ³]	%
1-propene, 2-methyl (CAS)	98	-	100	98	-	100	100	29	71
Benzene	408	384	6	408	739	-81	406	352	13
Butanol	505	352	30	505	-	100	413	232	44
Toluene	130	158	-22	130	59	55	181	220	-22
D5	239	80	67	239	79	67	235	134	43
Decanal	92	15	84	92	15	84	18	21	-17

Sulfur containing agents

Furan	334	199	40	334	-	100	324	125	61
Dimethyl sulfide	381	97	75	381	-	100	312	31	90
Carbon disulfide	379	201	47	379	28	93	298	138	54
Ethylene sulfide	30	-	100	30	-	100	19	-	100
2-Methylfuran	395	126	68	395	-	100	278	105	62
Propylene Sulfid	27	10	63	27	-	100	26	-	100
Thiophene	57	37	35	57	-	100	49	40	18
Dimethyl disulfide	142	61	57	142	6	96	143	73	49
3-Methyl thiophene	9	11	-22	9	-	100	19	16	16
Methyl-ethyl disulfide	9	-	100	9	-	100	4	-	100
Dimethyl trisulfide	10	-	100	10	-	100	14	-	100



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Conclusion for test site 2:

The following conclusion can be given: Similar species have been found like in the first measurement sequence in February 2011, which are CO_2 , H_2O , CH_4 , H_2S and sulfur containing agents such as sulfides or disulfides. In addition, also COS and CO could be identified by the FTIR measurements. Furthermore, the GC/MS samples showed a variety of aldehydes before the biofilter. They could not be found afterwards. After the biofilter, the aldehydes were drastically removed but a significant value of sulfur containing agents remained. These could be reduced by the plasma and the catalyst. Due to a variety of chemical agents in the off gas, it was not possible to identify the main chemical agents responsible for bad smell. Nevertheless, the results suggest that sulfur containing agents play a significant role.

5. Results for the test site 3 (sedimentation tank in Kozięglowy):

FTIR measurements:

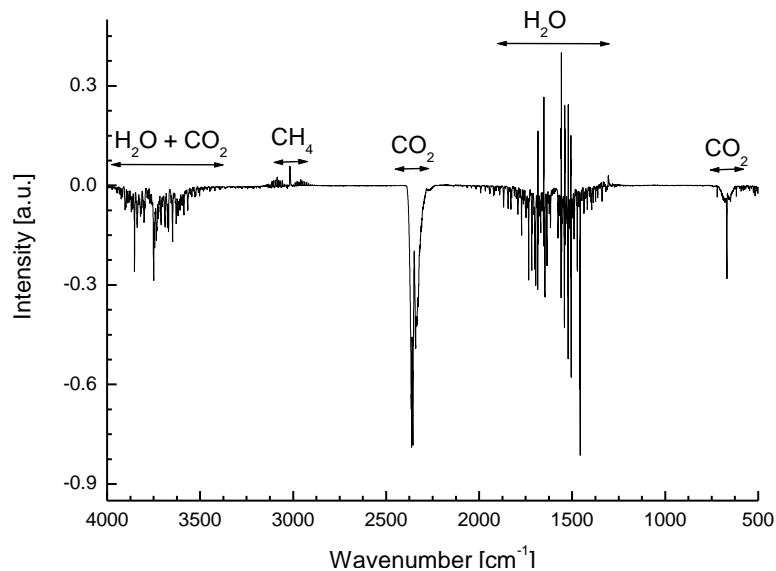


Fig. 9: Inlet of the plasma stage and the catalyst (300W/110°C) after sedimentation tank (Experiment #6 June 30th 2011).





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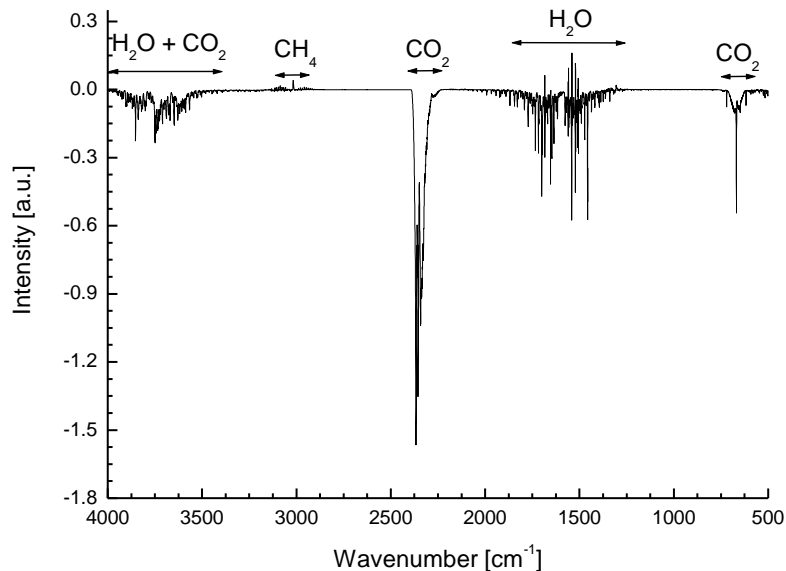


Fig. 10: Outlet of the plasma stage and the catalyst (300W/110°C) after sedimentation tank (Experiment #6 June 30th 2011).

Here, the CO₂ and H₂O peaks are negative, since the background spectrum was laboratory air, which had a higher CO₂ and H₂O level than the samples.

At the second test site, the sedimentation tank, no other different species than CO₂, H₂O and CH₄ could be registered for the measurements without scrubber. The underlying reason therefore is the spectra being overruled by H₂O. A subtraction also did not reveal any new species. There are only marginal differences in CO₂ and CH₄ concentration in the different modes and at the different positions in the system. These small differences can be explained by the admixture of fresh air at the plasma stage and the variation of gas mixture at different times of sampling.

For the use of the scrubber with H₂O₂ and NaOH, a similar statement can be made. There is no significant peak visible that can be assigned to a species different than the three already mentioned (CO₂, H₂O and CH₄). In case of the H₂O scrubber, no other species than CO₂ and H₂O can be detected. This is due to the fact of an enormous amount of water in the samples.

GC/MS measurements:

Similar to the results at the first measurement point, aldehydes, aromatic hydrocarbons and sulfur containing agents are the main components of the trace gases.

The results without scrubber also show that the sulfur containing agents are reduced by the plasma and the catalyst. In contrast to the other results, here much less agents are detectable at a lower concentration. For the sulfur containing agents, it can be said, that the plasma power does not have a huge impact on the reduction, but the temperature of the catalyst certainly has. This is in good agreement with the measurements of the FTIR. Anyhow, the olfactometry shows similar results for all three cases. The amount of VOC in trace gases is rising in most cases.

Table 8: Chemical agents identified by GC MS at experiment #1, #2 and #3 (June 29th and 30th, 2011).



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	#1 300W/240°C			#2 500W/240°C			#3 300W/180°C		
	Before	After	Red. rate	Before	After	Red. rate	Before	After	Red. rate
	[µg/m ³]	[µg/m ³]	%	[µg/m ³]	[µg/m ³]	%	[µg/m ³]	[µg/m ³]	%
Acetone	112	25	78	112	44	61	94	40	57
Acetic acid	75	-	100	75	-	100	51	60	-18
Benzene	38	35	8	38	25	34	14	15	-7
Toluene	74	85	-15	74	66	11	55	67	-22
Hexanal	39	51	-31	39	60	-54	34	59	-74
Xylol	27	55	-104	27	52	-93	13	26	-100
2-ethyl-1-hexanol	76	139	-83	76	125	-64	52	108	-108
D5	86	116	-35	86	86	0	25	45	-80
Decanal	52	17	67	52	16	69	23	20	13
Sulfur containing agents									
Carbon disulfide	33	11	67	33	14	58	16	11	31
Dimethyl disulfide	25	15	40	25	14	44	21	7	67
Dimethyl trisulfide	15	-	100	15	-	100	10	-	100
3Methylthiophene	-	6	-100	-	5	-100			
Dimethyl sulfide							14	-	100

Table 9: Chemical agents identified by GC MS at experiment #7 (NaOH scrubber) and #8 (H₂O scrubber) (June 30th, 2011).



PlasTEP

plasma for environment protection

	#7 300W/240°C with NaOH scrubber			#8 500W/240°C with H ₂ O scrubber		
	Before	After	Red. rate	Before	After	Red. rate
	[µg/m ³]	[µg/m ³]	%	[µg/m ³]	[µg/m ³]	%
Acetone	503	134	73	161	96	40
Acetic acid	97	132	-36	92	54	41
Isobutyl alcohol	10	60	-500	-	-	-
Benzene	18	14	22	14	9	36
Butanol	450	361	20	339	226	33
Pentanal	64	54	16	38	24	37
Toluene	70	51	27	72	77	-7
Hexanal	115	105	9	72	50	31
Xylol	27	23	15	16	17	-6
2-Ethylhexanol	113	143	-27	71	69	3
Nonanal	44	33	25	30	55	-83
D5	57	47	18	30	29	3
Decanal	24	38	-58	25	83	-232

Sulfur containing agents

Carbon disulfide	21	-	100	24	19	21
Dimethyl disulfide	21	7	67	24	9	63
Trimethyl disulfide				15	10	33

For the experiments with scrubber, the results look very similar to the experiments without a scrubber. The only difference is the amount of VOC in the trace gases which almost always decrease. But the reduction of sulfur containing agents is still going on.

Conclusion for test site 3:

FTIR measurements could not show a difference since the spectra were overruled by H₂O. Nevertheless, CO₂ and CH₄ can be identified. The GC/MS analysis showed that less aromatic hydrocarbons, aldehydes and sulfur containing agents are in the off gas than at the first test site. Nevertheless, the detected species are similar.

