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## CONDENSATE FROM A TWO-STAGE GASIFIER

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**ABSTRACT:** Condensate, produced when gas from downdraft biomass gasifier is cooled, contains organic compounds that inhibit nitrifiers. Treatment with activated carbon removes most of the organics and makes the condensate far less inhibitory.

The condensate from an optimised two-stage gasifier is so clean that the organic compounds and the inhibition effect are very low even before treatment with activated carbon. The moderate inhibition effect relates to a high content of ammonia in the condensate. The nitrifiers become tolerant to the condensate after a few weeks of exposure.

The level of organic compounds and the level of inhibition are so low that condensate from the optimised two-stage gasifier can be led to the public sewer.

### 1. BACKGROUND

Since the energy production from biomass is CO<sub>2</sub>-neutral, biomass gasifiers have a future as environmentally friendly energy supply. Therefore it is essential that new environmental problems are not created when biomass gasification is introduced to the market.

Until now, there has been too little focus on the potential environmental problems that condensate from gasifiers may create.

When the product gas from a gasifier is cooled below the dew point of the gas, a condensate is produced. This condensate may contain toxic organic compounds and inhibit nitrifiers in waste water treatment plants.

If the condensate needs to be disposed it is necessary to investigate the amount of toxic compounds and the amount of inhibition of nitrifying bacteria.

The two-stage gasification process was originally developed to gasify straw. When a dry fuel as straw is gasified, it is possible to evaporate and recycle the condensate to the process, thus preventing the process from producing tar water.

If wood chips, which have a high moisture content, are the fuel in a gasifier it is necessary either to

- dry the fuel and recycle the condensate
- clean and discharge the water into the public sewerage system.
- optimise the gasification process so that the condensate becomes so clean that it can be led to the public sewer without treatment.

For technical and financial reasons, the last two solutions may be preferable, and condensate and possibilities of cleaning the condensate from the two-stage gasifier were therefore investigated.

### 2. PURPOSE

The purpose of this work was to investigate if the condensate produced from a two-stage gasifier was clean enough, or with simple means could be cleaned enough, to be led to the public sewer.

### 3. TESTS

Condensate from two test runs with the 100 kW (thermal) two-stage gasifier was analysed for organic compounds and for toxicity to the nitrifiers (a specific group of bacteria converting ammonia into nitrate) in the waste water treatment plants.

Both samples were analysed before and after treatment with activated carbon from the gasifier. It is well known that activated carbon can remove certain organic compounds including PAH from waste water [2], [3].

The two samples of condensate were different since the gasifier was reconstructed and optimised between the two tests [1]. The condensates that were treated and analysed were from tests in March, 1998, and in September, 1998, when the gasifier had been reconstructed and optimised.

The four tested samples are numbered as follows:

- 1a: Condensate before optimisation of gasifier, filtered.
- 1b: Condensate before optimisation of gasifier, treated with crushed activated carbon and filtered.
- 2a: Condensate after optimisation of gasifier, filtered.
- 2b: Condensate after optimisation of gasifier, treated with crushed activated carbon and filtered.

**Treatment:** For each sample of condensate one part was filtered through a 0,45 µm filter and one part was treated with activated carbon.

Investigation of char from the two-stage gasifier documents that the char is an activated carbon with very good

adsorption data. [1] [4]. It was therefore decided to investigate the condensate before and after treatment with activated carbon produced by the two-stage gasifier. Activated carbon from a test of the 100 kW two-stage gasifier in January 1998 was used.

For the treatment, 5 grams of crushed activated carbon were stirred in one litre of condensate for one hour and then filtered through a 0,45 µm filter.

#### 4. ORGANIC SUBSTANCE IN THE CONDENSATE FROM A TWO-STAGE GASIFIER

Phenols and other organic compounds are formed during pyrolysis and Polyaromatic Hydrocarbons (PAH) are formed during further reactions. Some PAH's can cause cancer and are therefore not wanted in waste water and in fluegasses. The contents of Phenols, PAH and other organics have been investigated at RISØ and at VKI in Denmark.

##### 5.1 Organic substance in the condensate before and after cleaning with activated carbon

Table 1. Organic compounds of condensate from a two-stage gasifier before and after treatment with activated carbon

Sample	pH	NVOC mg C/L	Phenol mg/L	Naphthalen mg/L
1a	9,07	56	12	0,12
1b	9,29	31	0,01*	0,002
2a	9,17	4,8	0,001*	0,002*
2b	9,15	6,3	0,0005*	0,02

\*max

In Table 1 it is seen that the amount of organics in the condensate is dramatically reduced after the reconstruction and optimisation of the gasifier. Results from analysis of condensate from later tests (1999) are similar to the results after the optimisation shown in Table 1 (September 1998).

Further, it is seen in Table 1 that treatment of condensate from downdraft gasifiers that are not optimised will reduce the content of toxic organic compounds effectively.

##### 5.2 PAH's in condensate

Two samples of condensate from different days on the same test after the optimisation of the gasifier were analysed for 27 PAH's.

Table 2. Content of 27 PAH components in the condensate from the test in September 1998.

	9/9-98 µg/l	10/9-98 µg/l
Naphthalen	21	1,0
2-Methylnaphthalen	< 0,1	< 0,1
1-Methylnaphthalen	< 0,1	< 0,1
Biphenyl	< 0,1	< 0,1
Acenaphthylen	< 0,3	< 0,5
Acenaphthen	< 0,1	< 0,2
Dibenzofuran	0,2	< 0,1
Flouren	0,3	0,5
1-Methylflouren	< 0,1	< 0,1
Phenanthren	1,9	3,1
Anthracen	< 0,2	< 0,3
2-Methylphenanthren	0,2	< 0,1
2-Methylanthracen	< 0,1	< 0,1
1-Methylphenanthren	< 0,1	< 0,1
Fluranthen	0,3	0,3
Pyren	0,2	0,3
1-Benzoflouren	< 0,1	< 0,1
Benzo(a)anthracen	< 0,3	< 0,5
Chrysen	< 0,3	< 0,5
Benzo(b+j+k)flouranthen	< 0,3	< 0,5
Benzo(e)pyren	< 0,1	< 0,1
Benzo(a)pyren	< 0,2	< 0,4
Indeno(1,2,3-cd)pyren	< 0,2	< 0,4
Dibenzo(a,h)anthrecen	< 0,1	< 0,2
Benzo(g,h,i)perylene	< 0,2	< 0,4
Sum af 27 PAH'er	24	5

It is seen in Table 2 that the content of most of the components is so small that it is below the detection level. The most important difference between the samples of the 9th and the 10th September, 1998, is the content of Naphtalen. Naphtalen is toxic, and therefore the lowest value should be reached either by process optimisation or by treatment with activated carbon.

#### 5. INHIBITION OF NITRIFIERS FROM CONDENSATE

Waste water that is led to the public sewer should not inhibit the biological process in the waste water treatment plant. The most sensitive of the biological processes is normally nitrification.

To measure the inhibition of nitrifiers, a sample of waste water and sludge from a waste water treatment plant is used. The waste water and the sludge are mixed, and it is measured how much the nitrifying bacteria are inhibited in percentage.

In Denmark there are two limit values for 20% sample mixed with 80% sludge. If the inhibition is more than 50%, the waste water should not be allowed to be led to the public sewer.

If the inhibition is between 20-50%, further investigations of the waste water should be made. It should then be investigated if the sludge will become habituated to the

waste water, so that the inhibition will be reduced after some time.

If the inhibition is less than 20%, the waste water should be allowed to be led to the public sewer.

The experiments of the inhibition of nitrifying bacteria are made by Jes La Cour Jansen at Lunds Universitet, Sweden, [5].

#### 4.1 Inhibition of condensate from the two-stage gasifier

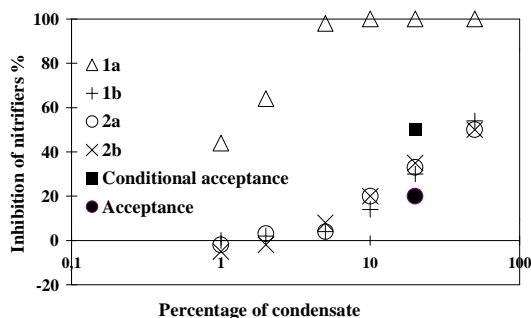


Figure 1. Inhibition of nitrifiers from condensate from a two-stage gasifier.

In Figure 1, the results of the inhibition tests are shown. Condensate labelled 1 is from the gasifier before the optimisation and label 2 is condensate from the gasifier after the optimisation. Label a is untreated condensate, and label b is condensate treated with activated carbon.

It is seen in Figure 1 that untreated condensate before the optimisation inhibits very much, but it is also seen that simple treatment with activated carbon reduces the inhibition so much that the cleaned condensate is in the zone where further investigations, “a tolerance test”, are necessary.

The inhibition curves from the treated and the untreated condensate after the optimisation are the same as from the treated condensate before optimisation. Treatment of the condensate after the optimisation with activated carbon could not reduce the inhibition further.

#### 5.1.2 Tolerance test of the condensate

Inhibition tests are made of the condensate from the gasifier after the optimisation to investigate if the sludge will become habituated to the waste water, so that the inhibition will be reduced after some time.

The tolerance test was made during three weeks. At start, there were small concentrations of condensate, but these were increased and kept at a level so that the condensate was about 40% of the water in the test.

In Figure 2 is shown the inhibiting effect of the condensate from the normal sludge that is used for the inhibition tests and from the sludge that has been exposed to the condensate.

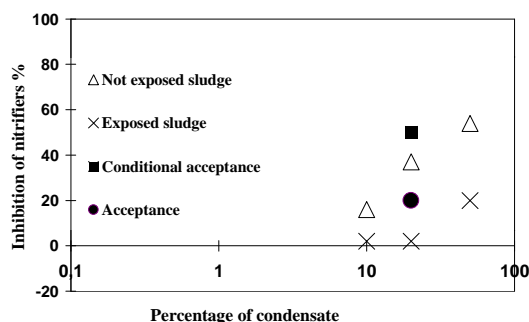


Figure 2. Inhibition of nitrifiers from condensate mixed in ordinary sludge and from sludge that has been exposed to condensate for three weeks.

In Figure 2 is seen that there is a moderate inhibition in the ordinary sludge equivalent to the results in Figure 1. The inhibiting effect of the exposed sludge is reduced to a level that will be accepted so the condensate can be led to the public sewer.

The content of ammonia in the condensate is high (1340 mg/l) so it was investigated if the inhibition was caused by the content of ammonia.

#### 5.1.3 Inhibition test of distilled condensate

To investigate if the inhibition was caused by the high ammonia content, 1000 ml of the condensate was distilled. Since the boiling point of ammonia is lower than that of water, ammonia will be distilled of first. The inhibition was then examined of the following three fractions of the distillate: The first 10% distillate: the next 70%, and the last 20%. See Table 3 and Figure 3.

Table 3. Simple chemical characterisation of condensate from the optimised two-stage gasifier before and after distillation.

Type of condensate	COD mg/l	Ammonia mg/l	pH
Condensate	56	1395	9,08
First 10 % distillate	32	8175	9,65
Next 70 % distillate	10	531	9,52
Last 20 % distillate	209	0	9,76

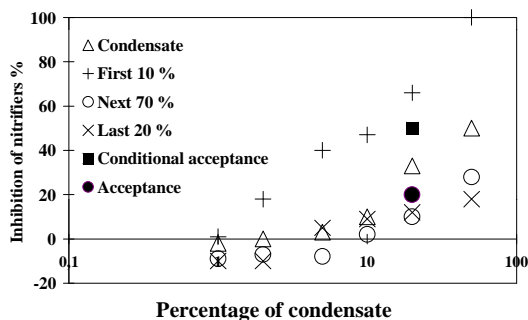


Figure 3. Inhibition of nitrifiers from condensate and three fractions of distilled condensate.

In Table 3 and Figure 3 is seen that the condensate contains 1395 mg ammonia pr. litre, and that the inhibition is similar to earlier tests (Figures 1 and 2). The first 10% distillate, which contains 6 times the concentration of ammonia, is inhibiting very much, while the other fractions inhibit less than required [5].

## 6. CONCLUSIONS

Regarding inhibition of nitrifiers, the condensate from the two-stage gasifier can be led to the public sewer after optimisation. Almost all the inhibition in the condensate of the two-stage gasifier can be related to the ammonia content [5].

The condensate from the gasifier before the optimisation was strongly inhibiting, but a simple treatment with activated carbon produced by the gasifier itself reduced the inhibition to an acceptable level.

The content of PAH and other organic compounds is very low in the condensate of the two-stage gasifier after optimisation.

To reduce the content even further and to ensure a low level, the condensate can be led through an activated carbon filter.

From these investigations of the condensate from a two-stage gasifier, the condensate from an optimised two-stage gasifier is considered to be so clean that it can be led to the public sewer in full compliance with the environmental legislation.

## ACKNOWLEDGEMENTS

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