FLASHPHOS

The complete thermochemical recycling of sewage sludge

DRYING-GRINDING EXPERIMENTS

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ACRONYM	DESCRIPTION
DS	Dry substance
PFD	Process flow diagram
STP	Sewage treatment plant

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EXECUTIVE SUMMARY

For practicable sludge treatment and phosphorus recovery processes, it is important to accept dewatered sludge as it comes from sewage treatment plants. This sludge is normally very wet – typically 20 to 30% dry substance content (DSC). For the FlashPhos gasifying step, however, very dry and fine sewage sludge is required as input material.

A standard procedure to dry and grind the sludge would be to use belt or drum dryers producing a coarse material, which would then be ground in ball mills usually present in cement plants. It is assumed that in a Thin Film Dryer due to its technical specifications, the sludge can be dried and ground at the same time. This would reduce FlashPhos' overall energy consumption and the necessary logistical effort.

In the tests reported here, the process parameters of a thin film dryer should be varied in order to evaluate if it is possible to obtain a dry material with a maximum of particles <300 µm, in order to be processed in the flash reactor without further treatment. The tests should prove the concept, which is planned to be further developed and optimised in a pilot dryer to be operated in an industrial environment in WP6.

The test results show that a decent mass fraction of fine particles can only be obtained when drying to very high dry substance (DS) contents. Another deciding parameter for the final particle size distribution is the DS content of the sludge feed.

In our tests with a poorly dewatered sludge (about 22% DS content, corresponding to typical products of decanters or screw presses), a set of parameters yielding a good compromise between dryer performance and generating fine particles could be found: At a feed rate of ~50 kg/h and a corresponding water evaporation rate of almost 40 kg/h, on average about 60 % of the dry sludge had a grain size smaller than 500 µm, and only about 10 % a grain size between 1 and 2 mm. Drying sludge with a DSC >33% (typical for well operated decanters or chamber filter presses) we could reach up to more than 80% of the mass with particle sizes <500 µm, reaching a water evaporation rate of about 29 kg/h.

Because as planned, only simple parameters have been varied in these tests, it is expected that more profound changes will strongly enhance the drying performance of the apparatus. These changes are planned to be tested in the above-mentioned pilot dryer, as special features of the dryer will be necessary, which could not be realised in the test campaign reported here.

These tests show clearly that the drying-grinding process can be feasible and indicate that the process should be optimised in the planned pilot dryer.

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1 INTRODUCTION

For the flash reactor to work properly, it is crucial that the sewage sludge is very dry (DS content > 95 %). Additionally, a small grain size in the order of 300 μm is required. This contradicts with the usual requirements of sewage sludge drying installations that aim for a minimum dust content in the dry product and DS contents of usually not more than 80 to 90 %.

The thin film dryer planned to be modified for the use in FlashPhos, due to its technical specifications, is suitable to produce the required properties. The following report describes the work done to find the necessary process parameters.

1.1 PURPOSE AND TARGET GROUP

The purpose of the tests reported here is to optimize a thin film drying process to give very fine and dry sewage sludge. The results are employed for designing the drying plant that will be delivered by SMS via WP4 and operated by USTUTT ISWA in WP6.

The results of these tests being a basis for the optimisation of the dryer-grinder are a start for the constant exchange with the Flash reactor modelling in WP2, the linked pilot plant design and engineering in WP4; via their dependence of input requirements there is also exchange with the evaluation of sludge availability in WP5 and thus the technical and economic evaluation of the entire FlashPhos concept (WPs 7 and 9).

Regarding the public interest, this report shall introduce a new application of the established thin film drying technology.

1.2 CONTRIBUTIONS OF PARTNERS

The practical input of this deliverable was accomplished by SMS. The experimental design and evaluation of the results were discussed with USTUTT ISWA. Feedback about the role of particle sizes in Flash gasification physics and chemistry was given by TU GRAZ.

2 OBJECTIVES AND EXPECTED IMPACT

The works summarised in this deliverable shall serve as proof of the dryer-grinder concept.

2.1 OBJECTIVES

- Vary the operating conditions of a standard thin film dryer and observe the effect on particle size distribution and DSC of the product
- Find optimal settings to approach the particle size distribution required for the Flash gasification
- Prepare design of pilot dryer and of process optimisation trials

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2.2 EXPECTED IMPACT

The successful pre-experiments show the feasibility of the drying-grinding process and will deliver the basis for the drying pilot trials.

Eventually, the drying-grinding concept contributes greatly to a practicable and energy-efficient FlashPhos process embedded in the European sewage sludge economy.

3 GENERAL DESCRIPTION

In this deliverable, SMS has set up a test plant in their test facilities in Pratteln, Switzerland. With this pilot plant, tests have been carried out in order to evaluate suitable process parameters for obtaining dry and fine sewage sludge. After each test, the DS content as well as the particle size distribution of the dry sludge was determined.

As feed product, municipal dewatered sewage sludge from the sewage treatment plant (STP) in Füllinsdorf close to Pratteln has been used.

3.1 SETUP AND WORKING PRINCIPLE OF THE TEST PLANT

The pilot plant employed for the tests is shown in the attached Process Flow Diagram (PFD).

The wet sludge was stored in a stirred vessel (B-1 in the PFD). It was fed to the dryer with an eccentric screw pump (P-1) that was directly attached to the storage vessel. Both, pump and vessel were arranged on a scale. The feed rate was determined by measuring the weight loss over time.

The pilot scale Thin Film Dryer (T-1) was heated with two thermal oil aggregates with 16 kW thermal power each. Inside the dryer, the product was dried (and ground). To minimize the air flow into the dryer, the dry product was discharged via two butterfly valves and was collected in a drum (B-2).

The vapours passed a trace-heated vapor dome (F-1) and an also trace-heated vapor line towards the condenser (W-1). In a shell and tube condenser, the water was condensed, the remaining off-gas was removed from the system via a radial fan and released to atmosphere after passing an activated carbon filter. The distillate was collected in a vessel (B-3) and subsequently canalized.

3.2 CHARACTERIZATION OF THE FEED PRODUCT

The sludge used for the tests was digested, mechanically dewatered sewage sludge from the STP located in Füllinsdorf, Switzerland (close to SMS test facilities).

Since storage stability of wet sewage is a critical issue, the sludge was wicked up at the STP shortly before the tests were carried out. The wet sludge was stored in several drums of 200 l each in a chilled room at ~6 °C for a maximum of seven days.

The original wet sludge coming from the STP had an average DS content of 33 %. Since this is a quite high value for mechanically dewatered sludge, water was added and mixed in for some of the tests to obtain different, more representative DS contents (16.5 – 33.7 %).

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3.3 PROCESS PARAMETERS

The parameters with which the drying-grinding process at atmospheric pressure can be influenced are feed rate, heating temperature, rotor blade arrangement and rotor speed.

3.3.1 HEATING TEMPERATURE

The heating temperature has large impact on the drying performance. Since variation in heating temperature can be compensated by varying the feed rate and since heating temperature is not expected to have major impact on the particle size, it was decided to limit the study to the two temperatures of 180 °C and 200 °C.

3.3.2 ROTOR SPEED

For normal drying tasks we aim to minimise dust formation. From the respective process development, we know that the rotor speed has a large impact on the form of the final product: The higher the rotor speed is, the finer the dry product becomes.

Based on this knowledge, in order to obtain the finest possible material, it was decided to set the rotor speed to a constant value close to the highest speed that can be achieved with the test dryer. This rotor speed in our test drier corresponds to typical values for large scale dryers.

3.3.3 ROTOR BLADE ARRANGEMENT AND FEED RATE

The rotor blade arrangement and the feed rate to the dryer were identified to be the key parameters to be varied during the tests. It is known that rotor blade arrangement (shape and angle of the blades) has a large impact on the dryer performance and on the shape of the final product.

For obtaining reasonable dryer sizes in large scale processes, the feed rate to the dryer should be as high as possible. Therefore, our study focused on finding a blade arrangement that allows high feed rates and at the same time results in a fine final product.

For the different rotor blade arrangements (see Table 1), various combinations of blade geometries and angles to the feed direction at deciding positions of the dryer (input, center, output side) were set up.

Remark: The actual shapes and positions of the blades are protected IP of SMS and are not disclosed in this public deliverable.

3.4 ANALYTICS

During the tests, the remaining moisture as well as the particle size distribution were determined.

The remaining moisture was measured with a standard infrared balance at a temperature of 105 °C.

The particle size distribution was determined via sieve analysis. The mesh sizes were 0.25, 0.5, 1.0, 2.0 and 4.0 mm.

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4 RESULTS AND DISCUSSION

Before starting the dryer after shutdown (overnight and for changing the rotor blade arrangement), it was heated for at least one hour to ensure that the body as well as the rotor are sufficiently hot. After start-up, parameters were varied during the running process. After start-up and after changing parameters, it was waited for at least 20 to 30 minutes before starting a test to ensure a steady state process. Each test was run for at least 30 minutes during which the heating temperature as well as the feed rate were monitored. Samples of the dry product were taken at the end of each test and directly analysed on the infrared balance and the sieve analysis device.

The thermal power consumption of the dryer was not monitored during the test. Since our test dryer as well as the heating medium pipes are only partially isolated, heat loss is much larger than in large scale plants that are properly isolated. Thus, such measurement would give unreasonable results. Furthermore, the absorbed thermal power per ton of water evaporation in a thin film dryer is mainly determined by the inlet and the outlet DS content of the sludge and can be calculated by an energy balance. For the conditions reported here, it is between 740 and 750 kWh/t.

All tests in which a stable and reliable dryer operation was reached are summarized in Table 1. In that table, only the mass fractions of particles with a grain size smaller than 0.5 and 0.25 mm are given. The entire particle size distribution as determined during the tests are not given in this report for reasons of clarity.

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Table 1: Summary of tests with significant results.

TEST NO.	ROTOR BLADE ARRANGE-MENT NO.	HEATING TEMPERA-TURE °C	FEED RATE KG/H	DS CONTENT WET SLUDGE %	DS CONTENT DRY SLUDGE %	DRY PRODUCT < 0.5 MM %	DRY PRODUCT < 0.25 MM %
2	1	180	40	32.7	98.7	--	--
3	1	180	45	32.7	97.5	--	--
4	1	180	65	32.7	93.6	24	10
5	1	180	47.5	32.7	94.5	30	9
6	1	180	35	32.7	97.9	40	17
8	1	200	60	33.3	90.8	15	6
9	1	200	33	33.3	99.0	41	15
10	1	200	45	33.3	98.0	25	9
11	2	180	44	33.7	99.5	81	52
12	2	180	35	33.7	99.8	82	60
13	2	180	18	33.7	100.0	84	37
14	2	180	30	16.4	99.2	54	29
15	2	180	16.9	16.4	99.3	34	12
16	2	180	30	16.4	98.9	28	4
19	4	180	52.5	16.5	92.4	33	15
21	4	180	50	16.5	--	--	--
22	4	200	50	16.5	98.7	43	15
24	5	200	30	21.7	99.3	31	9
25	5	200	54	21.7	98.6	70	30
28a	5	200	64.3	21.7	97.2	27	11
28b	5	200	51	21.7	99.0	68	39
28c	5	200	51	21.7	99.9	56	32
29a	6	200	48	23.6	99.8	42	12
29b	6	200	48	23.6	99.8	66	35

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The test show that it is possible to dry the dewatered sludge to DS contents > 99 % and obtain a fine and dry product. Figure 1 shows the dry product obtained in one exemplary test.

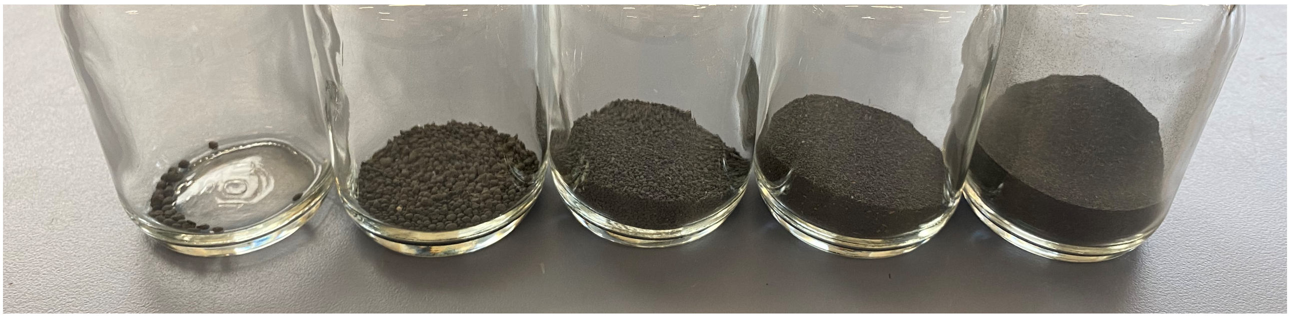

Figure 1: Dry sludge from one exemplary test. From left to right: Grain size > 2 mm; > 1 mm; > 0,5 mm; > 0.25 mm; < 0.25 mm

In the tests, it was observed that a decent fraction of fine particles can only be obtained when drying to very high DS contents. The fraction of fine particles with a grain size smaller than 0.5 mm and 0.25 mm versus DS content of the dried sludge is shown in Figure 2.

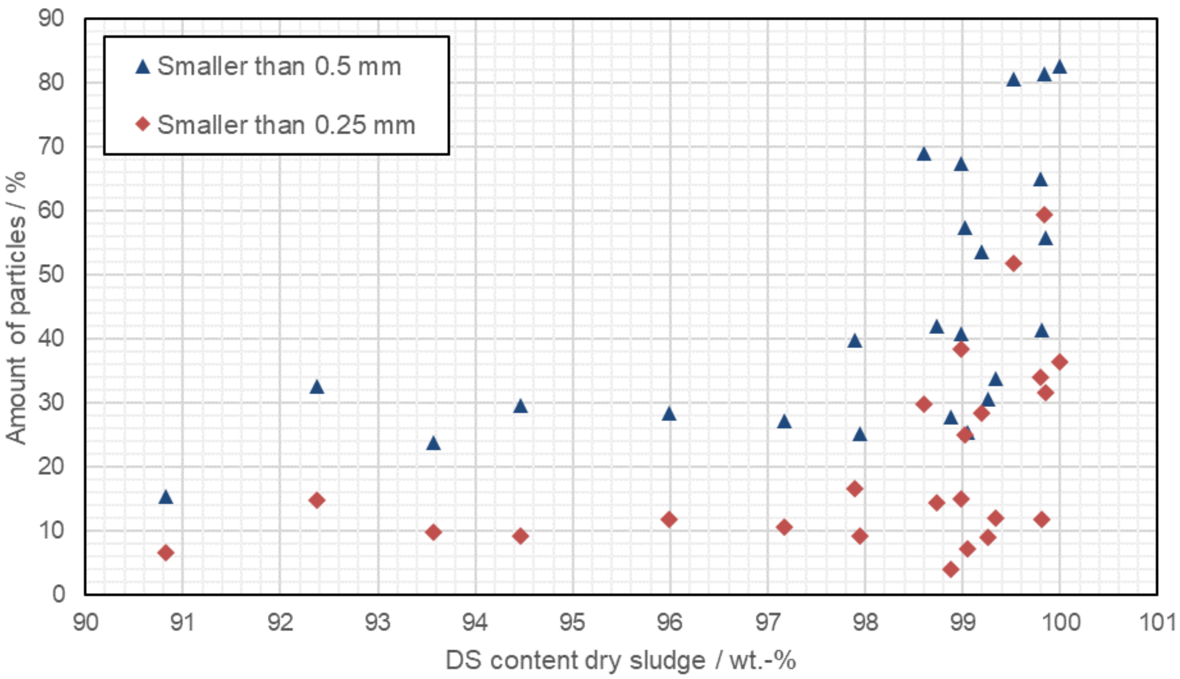

Figure 2: Dependence of mass fraction of fine particles from DS content.

As can be seen, the fraction of fine particles drastically increases with increasing DS content. It can be concluded that the product needs to be dried to at least 99 % if one is aiming for producing fine particles. However, in all tests that are considered to be relevant, 80 to 90 % of the particles had a grain size smaller than 1 mm and virtually all of the particles are smaller than 2 mm.

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5 DEVIATIONS FROM THE PLAN

There were no deviations from the plan.

6 LINKS WITH OTHER WPS

For links to other WPs, please see section **Fehler! Verweisquelle konnte nicht gefunden werden.** of this document.

7 SUMMARY AND CONCLUSIONS

In the tests, a set of parameters that yield a good compromise between dryer performance and generating fine particles could be found. A feed rate of ~50 kg/h has been achieved. That is, at the given DS contents of the sludge, in accordance with what was expected.

With this feed rate and a DS content typical for decanter sludges, an average of ca. 60% of the dry sludge has a grain size smaller than 0.5 mm, and only about 10% a grain size between 1 and 2 mm. (Particles such as hair contained in sewage sludge cannot be influenced in their size by the dryer.)

Also, the DS content of the feed showed to play an important role for the reachable fraction of fine particles. Higher inlet DS contents, and thus well dewatered sludges like filter cakes lead to a significantly finer material (>80% of grains <500 µm in our experiments).

A clear link between final DS content and particle size distribution was observed. All tests obtaining the smallest grain sizes resulted in DS contents of higher than 99%. In contrast to the originally planned 85%, the much drier material will serve as a much better fuel.

With these results, our simple pre-experiments, varying only one major parameter, could clearly prove the concept of the planned dryer-grinder. With further modifications of the dryer geometry like reducing the distance between blades and dryer wall, the fraction of particles smaller than 300 µm can be maximised. These changes will be realised in the pilot dryer to be designed and constructed in the following months in WP4, and after each optimisation test to be performed in WP6.

Our final conclusion is that the present D 3.1 is a solid basis to continue our work as indicated in Annex 1B of the Grant Agreement.

8 ANNEX: PROCESS FLOW DIAGRAM OF THE TEST DRYER

(see following page)

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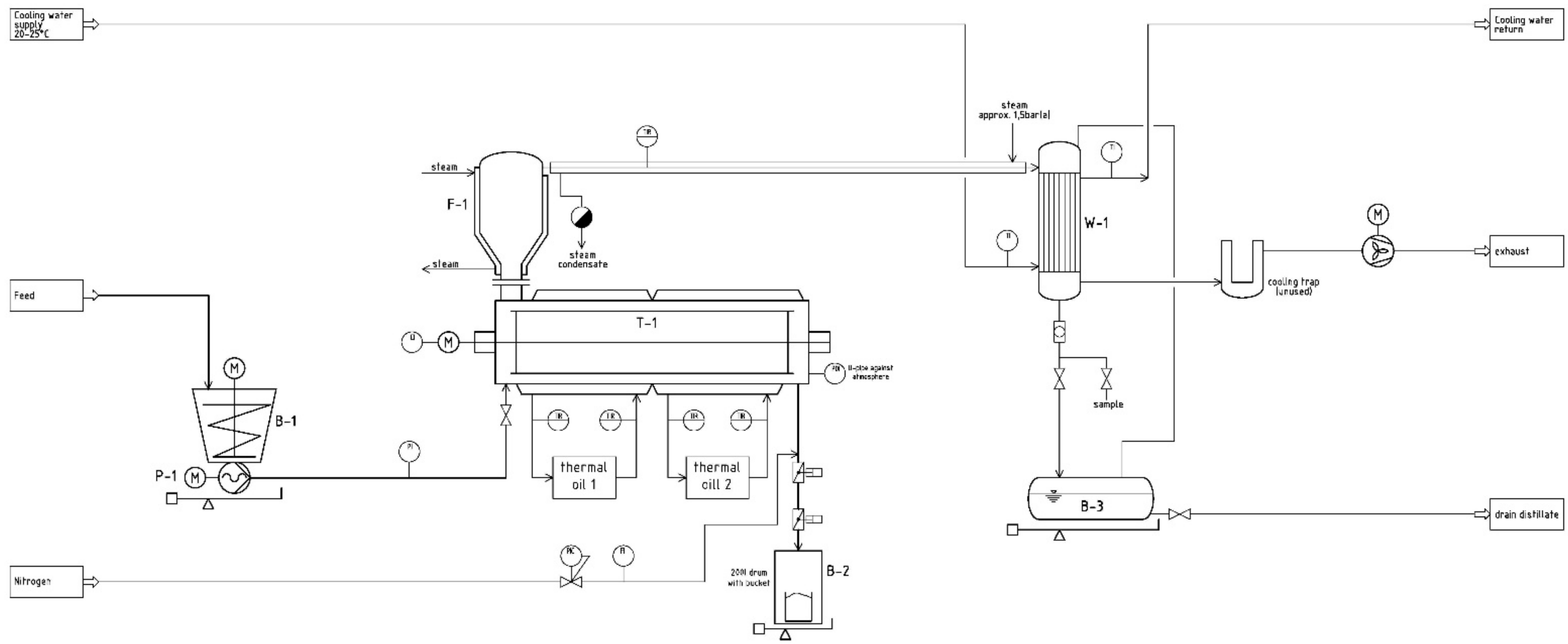

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