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IMPACT OF STORAGE DURATION ON EMISSIONS OF AMMONIA AND VOLATILE ORGANIC COMPOUNDS DURING CONVECTIVE DRYING OF URBAN RESIDUAL SLUDGES

L. Fraikin[1], B. Herbreteau[2], X. Chaucherie[2], F. Nicol[2], T. Salmon[1], M. Crine[1], A. Léonard[1]

[1]*Laboratory of Chemical Engineering; University of Liege*
Institut de chimie B6c, Allée de la chimie, 4000, Sart Tilman, Belgium
Tel.:+32 4 366 35 19, E-mail: Laurent.fraikin@ulg.ac.be

[2]*VEOLIA Environnement Recherche et Innovation*
Zone portuaire de Limay, 291 Avenue Dreyfous Ducas, 78520, Limay, France
Tel.:+33 130 98 54 54, E-mail: francois.nicol@veolia.com

Abstract: Drying has become an important step within the context of sludge management. Sometimes, sludges from several wastewater treatment plants are centralized in order to dry them at an acceptable cost. Depending on sludge supply, there can be a delay between delivery and feeding into the dryer. This paper focuses on the impact of sludge storage duration on the drying kinetics and the exhaust emissions of volatile organic compounds, VOCs, and ammonia. Results show that, after 20 days of storage the drying time is multiplied by 1.5, and the emissions of VOCs and NH_3 are multiplied by 5 and 40, respectively.

Keywords: sludge, convective drying, emissions, VOCs, ammonia

INTRODUCTION

According to new environmental regulations, municipalities will have to face with growing amounts of urban residual sludge, all over Europe (Spinosa, 2001; Fitzmorris, Sarmiento et al., 2009). Two major options are commonly considered for sludge disposal: incineration and landspreading. Drying remains an interesting and sometimes obligatory pre-treatment after mechanical dewatering. It can indeed reduce the water content below 10% of the total mass. This obviously decreases the mass and volume of waste and, consequently, the cost of storage, handling and transport. The removal of water to such a low level drastically increases the lower calorific value, transforming the sludge into an acceptable combustible. Furthermore, the dried sludge can be a pathogen free, stabilized material depending on the temperature treatment.

Convective dryers are largely used to remove water from sludge. The main advantages of the so-called direct dryers are: technology simplicity, absence of rotating parts, robustness, easy shape control by granulation or extrusion, and relatively low sensitivity to initial water content. Nevertheless this configuration also implies two major drawbacks: the complexity of the peripherals, and a large volume of air to be treated before being released into the environment. Even though some works have been published concerning odours and emissions produced within wastewater treatment facilities (Dincer and Muezzinoglu, 2008; Sekyiamah and Kim, 2009; Winter and Duckham, 2000), very few data can be found about the gaseous emissions related specifically to wastewater sludge drying (Leonard, Martin et al., 2007; Leonard, Nicolas et al., 2008; Deng, Yan et al., 2009). However, their characterization is of high importance, in order to perform an efficient design of the odour treatment facility. In the particular case of centralized treatment facilities, there can be a delay between sludge delivery on site and its feeding into the dryer. During this time span the wet product can evolve, leading to possible modifications of the drying related gaseous emissions and/or kinetics.

Within this context the Laboratory of Chemical Engineering of Liège University in collaboration with VEOLIA Environnement Recherche et Innovation performed this preliminary work in order to investigate the influence of sludge storage duration on the gaseous emissions produced during convective drying, especially on the release of volatile organic compounds and ammonia.

MATERIALS AND METHODS

Sludge samples

Sludge is collected after the mechanical dewatering step at the "Grosses Battes" wastewater treatment plant located near Liège (Belgium). The dewatering is realised using a belt filter. The initial dry matter content of the sample is close to 14.5%. For experiments, the sludge is usually stored at a temperature of 4°C in order to minimize sludge evolution and keep the same product quality throughout a series of trials. In this study, the sludge is stored in a tightly closed jar at a temperature of 12°C to obtain storage conditions close to the industrial outdoor conditions. Indeed, activated sludge is an heterogeneous mixture of microorganisms, mineral particles, colloids, organic polymers and cations, which can evolve during storage.

Pilot-scale dryer

Before drying, sludge samples are extruded through a circular die of 10 mm. The drying experiments are carried out in a discontinuous pilot-scale dryer (Fig. 1) reproducing most of the operating conditions prevailing in a full-scale continuous belt dryer. Ambient air is heated up to the required temperature by an electrical heating device, and can be humidified by adding vapour. Hot air flows through the bed of sludge extrudates, which lies on a perforated grid, linked to scales. Three operating parameters are controlled: the temperature, the superficial velocity and the humidity of the air.

The initial mass of the sample is 300 g and is weighed on-line during the drying test every 30 s.

The humidity content of the air is checked on-line with a cooled mirror dew point hygrometer.

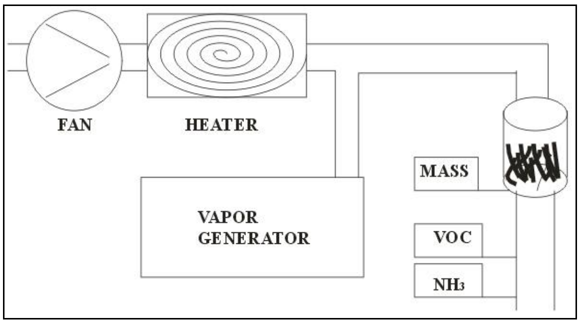

Fig. 1. Pilot-scale dryer

Gaseous analysers

The concentrations of volatile organic compounds (VOCs) and of NH3 are monitored in the exhaust pipe every 30 s.

The VOCs concentration is detected by a Flame Ionisation Detector (FID) and the NH_3 concentration is obtained using an infrared analyser.

Experimental strategy

Drying tests are carried out at the day of sampling, and then after 4, 10 and 20 days. These tests are realised under the same operational conditions, i.e. velocity: m/s; temperature: 140°C and absolute humidity: 0.005 $kg_{water}/kg_{dry\ air}$). For each trial, the drying kinetics and the emission of VOCs and NH_3 are recorded.

RESULTS

Drying behaviour

Fig. 2 shows the loss of mass of samples vs. time. The mass of the samples decreases with time. The drying kinetics are clearly affected by storage duration: the older the sludge, the slower the loss of mass. Fresh sludge dries in 350 min in comparison with a 20 days old sludge which dries in 550 min, i.e. a drying 1.5 times longer. Thus, energy can be saved by drying the sludge as soon as possible after dewatering.

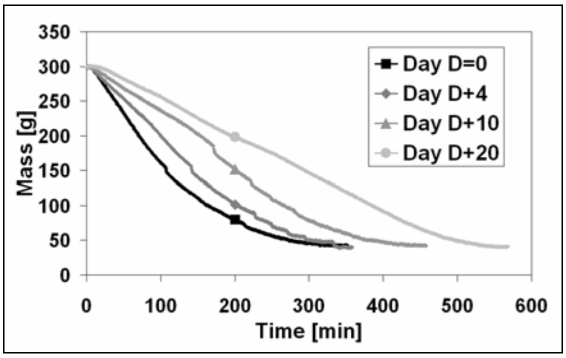

Fig. 2. Mass vs. time

Gaseous emissions: Volatile Organic Compounds

Fig. 3 shows the VOCs concentration evolution with time. Emissions gradually increase at the beginning of drying (less than 35% DS) to reach a maximum and then start to decrease when the dry solid content is superior to 75%. The emissions of VOCs continue after the end of drying, i.e. once all the water has been removed. As the sample is heated up, the volatility of organic compounds is increased: the higher the sample temperature, the more intense the emissions. The decrease of VOCs emissions could be explained by the progressive depletion of the pool of volatile organic compounds within the sample. Fig. 3 seems also to indicate that higher concentrations are detected for increasing storage durations. This is not surprising as the storage temperature, 12°C, does not restrict sufficiently the bacterial activity, so that fermentation can occur. This is confirmed by Table 1 showing cumulated VOCs emissions during the whole drying process.

The first column of Table 1 presents the mass of VOCs, expressed in grams of methane equivalent. The second column indicates the ratio between the quantity of VOCs measured on the testing day and the one obtained on the day of sludge sampling. Storage has two negative impacts on sludge convective belt drying: the drying time is increased, as well as the VOCs emissions, which are multiplied respectively by 2, 4 and 5 for sludge stored 4, 10 and 20 days-long.

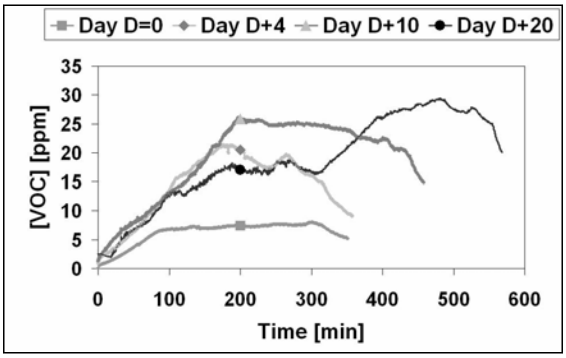

Fig. 3. Concentration of VOCs vs. time

Table 1. Cumulated emissions and ratio between quantity of VOCs on the testing day and the quantity of VOCs on the sampling day

Storage time (d)	Mass CH_4 (g)	$(m_{CH4})/(m_{CH4})_0$
0	306	1
4	716	2
10	1225	4
20	1494	5

Gaseous emissions: Ammonia

Fig. 4 shows the concentration of NH_3 vs. time. The emissions increase strongly shortly after the beginning of drying to reach a plateau and then decrease sooner than for VOCs emissions: around 30% DS. The NH_3 emissions may continue after the end of drying (elimination of water) if the quantity of ammonia is important into sludge.

It is supposed that the emissions of NH_3 are related to the evaporation of water: emissions evolve roughly in the same way as the drying rate. The reduction of ammonia emissions may be due to the weak water flow and the reduction of the concentration of NH_3 within the sample. The results of this work are not sufficient to prove this assumption but open the way for further investigations.

The age of sludge influences the emissions of NH_3: emissions increase with storage duration, as already observed for VOCs. This can be attributed to fermentation processes occurring within the sludge and producing ammonia.

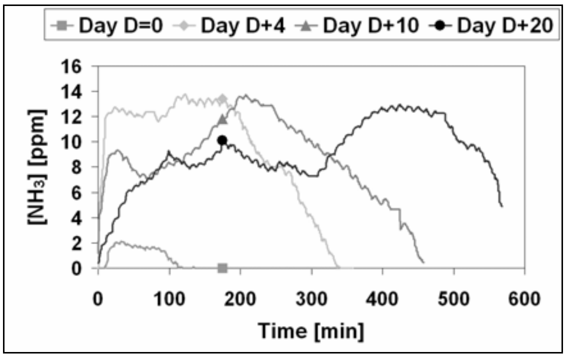

Fig. 4. Concentration of NH_3 vs. time

Table 2. Cumulated emissions and ratio between quantity of NH_3 on the testing day on the quantity of NH_3 on the sampling day

Storage time (d)	Mass NH_3 (g)	$(m_{NH3})/(m_{NH3})_0$
0	21	1
4	616	29
10	734	35
20	851	40

Table 2 presents in the first column the quantity of NH_3 released during the whole drying process and in the second one the ratio between the quantity of NH_3 measured on the testing day and on the sampling day. Once again with increasing storage durations both the drying time and the emissions are increased. The NH_3 emissions are multiplied by 29, 35 and 40 for sludge stored during respectively 4, 10 and 20 days.

CONCLUSIONS AND PERSPECTIVES

This study shows the influence of storage at a between fridge and room temperature on sludge drying kinetics and associated gaseous emissions. Since the bacterial activity is not sufficiently weak at this temperature, sludge continues to be digested. This alteration involves a deceleration of the kinetics of drying, which requires higher energy consumption. Moreover, the emissions of volatile organic compounds and ammonia also strongly increase with increasing storage duration. This should be taken into account when designing drying plants, and especially the odour treatment facility.

This preliminary study was performed with one type of sludge (activated sludge). In further studies, other types of sludge will be considered in order to see the influence of several treatments (e.g. digestion or liming) on the emissions of VOCs and ammonia.

NOMENCLATURE

DS	dry solid	%
(m_{CH4})	mass of methane	g
$(m_{CH4})_0$	mass of methane on collect day	g
(m_{NH3})	mass of ammonia	g
$(m_{NH3})_0$	mass of ammonia on collect day	g
$[NH_3]$	ammonia concentration	ppm
[VOCs]	volatile organic compounds concentration	ppm

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