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Review on fundamental aspect of application of drying process to wastewater sludge

Lyes Bennamoun [a,*], Patricia Arlabosse [b], Angélique Léonard [a]

[a] Laboratory of Chemical Engineering, Department of Applied Chemistry, University of Liege, Bat. B6C, Sart Tilman, Liege 4000, Belgium
[b] Université de Toulouse, Mines Albi, CNRS, Centre RAPSODEE, Campus Jarlard, F-81013 Albi cedex 09, France

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ABSTRACT

The objective of this work is to give the fundamental information that should be known about wastewater sludge drying. Three methods are mainly applied: convective drying, conductive drying and solar drying, each one presenting different characteristics. When applying convective drying three phases are distinguished: adaptation phase, constant drying rate phase and falling drying rate phase. Experimental works show that several parameters influence the drying kinetic during this process, such as the origin of the sludge and operating conditions. Imaging techniques allow observing three phenomena that happen during convective drying: shrinkage, cracks and skin formation. When applying conductive drying and considering the torque variations, the product passes through: pasty phase, lumpy phase and granular phase. The results show no regular shape of the drying kinetic with high values of the drying rate and the heat transfer coefficient during the first phase. A special focus is given into the sticky phase which reduces performances of the dryer. The third applied drying method is solar drying, which depends wholly on climatic conditions, such solar radiations and air temperature. Besides, for this method no regular shape of the drying kinetic can be observed, with high drying rate values during favorable conditions and low drying rate values during unfavorable conditions. The presented studies dealing with solar drying of wastewater sludge are limited to the variations of the different air temperatures registered inside and outside the drying chamber with the product temperature and their humidity with study of the pathogen reduction. Finally, some innovative developed methods are exposed in this review, such as the use of frying and super-heated steam.

Contents

1. Introduction

The quantity of municipal sewage sludge is in permanent increase. China, The European Union and The United States are three major contributors with 9.18 million tons of dry solid sludges in 2009, 11.7 million tons in 2010 and more than 8 million tons of dry solids in 2010, respectively [1–2]. Table 1 gives results of the physico-chemical composition and the metal contents with the range of variability of a

* Corresponding author. Tel.: +32 4 366 47 23; fax: +32 4 366 44 35.
E-mail addresses: Lyes.Bennamoun@ulg.ac.be, lyes_bennamoun@yahoo.ca (L. Bennamoun).

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Table 1
Municipal sludge characteristics with metal content [3].

Parameter	Primary	Secondary
Total solids (TS) (%)	3.0–7.0	0.5–2.0
Volatile solids (% of TS)	60–80	50–60
Nitrogen (N, % of TS)	1.5–4.0	2.4–5.0
Phosporus (P_2O_5, % of TS)	0.8–2.8	0.5–0.7
Potash (K_2O, % of TS)	0–1.0	0.5–0.7
Heat value (kJ kg^{-1}, dry basis)	23,000–30,000	18,500–23,000
pH	5.0–8.0	605–8.0
Alkalinity (mg l^{-1} as $CaCO_3$)	500–1,500	580–1,100
Metal contents (mg kg^{-1}, dry basis)	Range	Median
Arsenic	1.1–230	10
Cadmium	1–3,410	10
Chromium	10–99,000	500
Copper	84–17000	800
Lead	13–26000	500
Mercury	0.6–56	6
Molybdenum	0.1–214	4
Nickel	2–5,300	80
Selenium	1.7–17.2	5
Zinc	101–49,000	1700
Iron	1,000–154,000	17,000
Cobalt	11.3–2,490	30
Tin	2.6–329	14
Manganese	32–9870	260

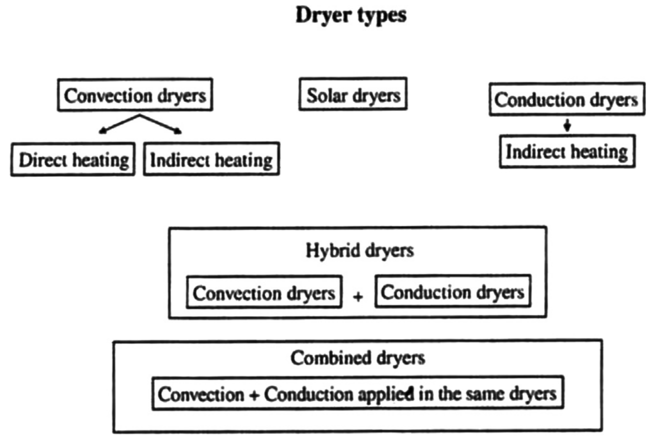

Fig. 1. Types of dryers used for sludge wastewater drying [2].

specific municipal sludge [3]. Due to the presence of important quantities of micronutrients such as iron, zinc, copper and manganese and macronutrients such as carbon, nitrogen and phosphorus, incorporating sludge in agriculture like a complementary fertilizer is proposed as a management option. Of course this solution cannot be realised without elimination of hazardous compounds such as arsenic and reduction of the pollutant concentrations by applying some treatments [4]. Otherwise, wastewater sludge can be directed for other industrial sectors such as incineration.

It is evident that for all proposed wastewater sludge management options, drying constitutes an important step. It reduces the volume of sludge and consequently decreases the cost of handling, transport and storage of the final product. In addition, it increases the calorific value of the wastewater sludge which permits to use it, as reported by Arlabosse et al. [2], like a fuel or a co-fuel in cement kilns, coal-fired power plants, municipal waste incinerators and mono-incinerators. Accordingly waste to energy is proposed as an alternative solution for sludge management. Again, the statistics [2] show that, for the most important producers, between 40% and 50% of the dried sludge, are used in agriculture. About 27% and 22% of the dried sludge produced by respectively the European Union and the United States are directed for incineration or thermal treatment. They also success to reduce the landfill practice, which can be considered as harmful for the environment, to only 14% and 17% of the total produced quantity with rigorous rules and directives for its application. However, China is still practicing landfilling, with more than 30% against a low percentage of around 3% of the dried sludge which is directed to the incineration or thermal treatment.

The technological progress, in the drying field, has allowed developing several techniques that can be divided into three main modes: convective drying, conductive drying and finally solar drying. Nevertheless, there is possibility to combine different drying methods and consequently to have hybrid dryers or

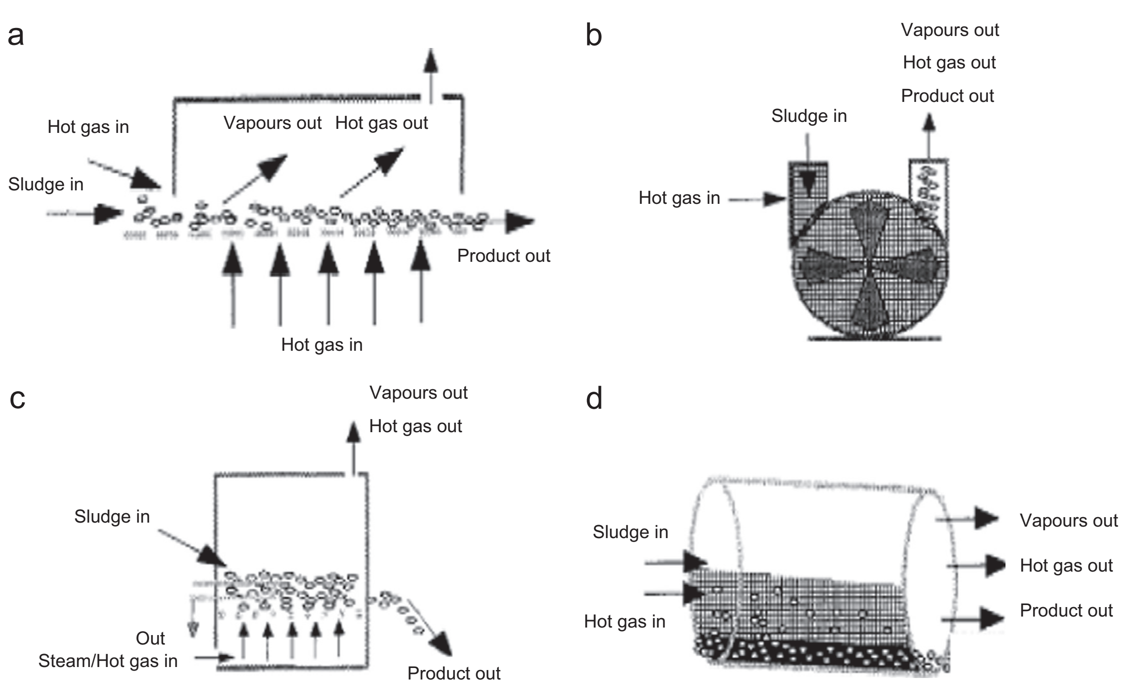

Fig. 2. Representations of some industrial convective sludge dryers [8]: (a) belt dryer, (b) flash dryer, (c) fluidized bed dryer, (d) rotary dryer.