

ALTERNATIVES OF DOMESTIC WASTEWATER SLUDGE DRYING PROCESSES FOR ENERGY RECOVERY : A REVIEW

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ABSTRACT

As communities grow, cities need to increase their capacity to collect and treat domestic wastewater. The need of larger domestic wastewater treatment plants and proper disposal of its solid waste has attracted the scientific community to research about new technologies that will use those systems and waste as a way to generate energy. The moisture content of a fuel affects the combustion products and the energy released by the reaction. Therefore, in order to make biomass to be a viable fuel option, the technological and scientific challenges of the drying process of wastewater sludge must be faced and overcome so the lowest moisture content level is achieved. Conventional drying processes as for example, direct and indirect thermal drying, are commonly used. However, other processes using renewable energy as for example solar drying are also being studied by the scientist around the world. Moisture content, physical-chemical properties as for example, heating values, composition, ash fusibility are all relevant properties taken into consideration when choosing a fuel for a specific application. The herein review is intended to present some existing domestic wastewater drying processes, alternative ways of improving the efficiency of those processes.

Keywords: drying processes, wastewater sludge, moisture

NOMENCLATURE

US EPA - United States Environmental Protection Agency

INTRODUCTION

The inadequate disposal of the sludge from domestic wastewater treatment plants is puts the

environment in danger due to its pathogenicity and due to presence of contaminants.

Logistics is also an issue, since high cost is associated to the large amount of sludge that must be transported, stored and disposed. According to Werther and Ogada (1999), domestic sludge can be used as a fertilizer or used as fuel for heat generation. Those are options have the potential to be explored since landfills are common in Brazil (Bringhenti *et al.*, 2018).

Chemical and biological components of domestic wastewater may vary. According to Luts *et al.* (2000) the composition of domestic waste water is 99.99% of water and 0.01% of solid. Of those 0.01% of solid, 70% are organic and 30% are inorganic solid.

According to Savi *et al.* (2020), biomass generated from wastewater sludge can be used to produce biofuels and bioenergy, as for example, biogas and its use to generate electricity at the treatment plant.

There is also the possibility of applying thermochemical processes to recover the energy for the sludge. However, cost effective ways of reducing the amount of moisture of the sludge must be found.

The herein study has the objective to present alternatives presented by the scientific community to reduce the moisture of domestic wastewater sludge aiming its use in energy recovery.

GENERATION AND STORAGE OF WASTEWATER SLUDGE

According to the Diagnose of Water and Wastewater Services performed by the Brazilian National System of Information in 2018 (Brasil, 2019), the wastewater treatment system had opened 1.3 million of new plants, indicating 4.2% growth comparing to the previous year.

In 2018, 74.5% of all the wastewater generated in Brazil was collected and only 46.3% was treated, the equivalent of 4.18 billion of m³ for the year of 2017 and 4.3 billion of m³ for the year of 2018, an increase of 2.9% (Brasil, 2019).

According to Batista (2015), 20-35g of solid waste from the aerobic treatment is produced from anaerobic treatment and 3 -15 g is produced from wastewater treatment plant per capita.

The toxic and pollutant components of the wastewater sludge make it an environmental problem, the high cost associated to its allocation and treatment make it an economic issue, since it represents 35-50% of all costs of the treatment plant. (Velden *et al.*, 2008).

The location where the wastewater treatment plant will be placed must have a large amount of available land which has becoming more and more hard to be found. The project of the treatment plant must have provision for residue elimination and full elimination of pathogenic components.

Pyrolysis is a process by which heat is provided in absence of oxygen and the biomass is thermally decomposed in three components: i) solids (carbon residue, combustible material); ii) liquid (bio-oil) and iii) gases (mixture of combustible gases). In the gasification process, there is the thermochemical conversion of a material into combustible gases and ashes. The combustible products of pyrolysis and gasification can then be burnt and the heat generated used to dry the sludge.

MOISTURE REDUCTION OF DOMESTIC WASTEWATER SLUDGE

Pre-treatment of solids is essential for its use as an alternative source of energy. Moisture is not only relevant from the energetic point of view but it is also relevant when considering transportation and storage (Simão, 2011). Reduction on moisture content will reduce volume and cost, since both are proportionally related storage and transport. Thermochemical conversion is more effective when moisture content is low. Domestic wastewater sludge must be composed of 28-33% of solid for the biomass to be burnt without the addiction of any other fuel (Bennamoun *et al.*, 2013; Batistella *et al.*, 2015).

The dehydrated wastewater sludge, even after centrifugation, can still have humidity ranging from 70 wt.% to 90 wt.%, which makes the direct energy recovery unfeasible (Bianchini *et al.*, 2015; Kijoj-Kleczkowska *et al.*, 2016; Nathanson e Ambulkar, 2020).

Lignin is a solid byproduct of the bioethanol production and is impregnated in the space between the porous of wastewater sludge to produce hybrid fuels. According to Park *et al.* (2019) the sludge must go through a drying process for 24h at 105°C to remove enough moisture to make the lignin impregnation viable.

SLUDGE DRYING PROCESSES

According to Khanlari, *et al.* (2020) an effective sludge drying process requires a significant amount of energy. However, there are energy conversion methods that can be used to recover energy from other processes that would be wasted.

Not all the materials need to go through the drying process, but for those that do, exhaustion gases from the combustion of other processes can be used as heat source to dry them and remove moisture (Dias *et al.*, 2012). According Uasuf and Becker (2011), drum dryer motors can use exhaustion gases as heat source for the drying process. The cost for this type of process is associated to the amount of sludge to be dried.

Calvo *et al.* (2013) conducted their research using a fuel composed of 60% of forest biomass and 40 wt. % of wastewater sludge. Before their being

mixed, the fuels were air-dried. The forest biomass moisture content was reduced to 5.82% and the sludge moisture reached 3.85 wt. %.

According to Bennamoun *et al.* (2013), the convective drying is performed in two stages: a stage where the drying rate is constant and a phase of decreasing drying rate. Several parameters influence the kinetics of the process as for example, the type of the domestic sludge.

The most common convective dryers are: belt dryers, flash dryers, fluidized bed dryers and rotary dryers. The energy consumption varies according to the type of drier from 700 kWh to 1400kWh per ton of evaporated water. The specific drying rate also varies from 0.2 kg/m²h (flash dryer) to 30 kg/m²h for belt dryers (Bennamoun *et al.*, 2013).

Convective drying is the physical concept applied to biodrying, in which heat is generated from biodegradation of organic matter facilitated by mechanically controlled aeration (Cai *et al.*, 2012). The aeration controls the temperature of the stack improving the evaporation of the water in the sludge (Cai *et al.*, 2012).

Bianchini *et al.* (2015) proposed a study where the heat for the drying process is from the exhaustion gases without using heat exchangers from a power plant. This concept aims to reduce the moisture content of the domestic sludge in 75 wt. %.

With the intent of reducing energy consumption and investment in equipment, Zhu *et al.* (2012) studied the efficiency of drying at low temperature (150 °C, 175 °C e 200 °C) for different shapes of sludge samples: cake, cylindrical and spherical. The studied pointed out that the cake shape had the highest drying efficiency. Due to the specific surface, the spherical shape presented the lowest drying efficiency. The highest efficiency was 40% reached in 3h of drying at 200°C.

Avelar *et al.* (2018) investigated a drying system of industrial sludge using hot gases from a coal furnace at 100±20 °C. They also used eucalyptus chips, which improved the efficiency of the drying system.

Fluidized bed dryers, rotary drum dryer and continuous flow dryer are examples of direct contact dryers. Since those technologies use a mixture of combustion gases and water vapor, they generate an expressive amount of organic vapor. In indirect contact dryers, the thermal energy from the exhaustion gases are transferred to the sludge by a heating surface. The combustion gases and vapors are exhausted through a separated pathway, making the treatment of the emissions easier to be done (Brechtel *et al.*, 1990).

Batistella *et al.* (2015) studied the gaseous emissions generated by the combustion of an anaerobic sewage sludge in a moving bed reactor. They showed that the level of CO was within the emission legal limits during the combustion process.

They showed there was an increase of CO concentration in the drying process due to high level of oxygen and high temperature (353.95 ± 18.25 °C). The SO₂ concentration was higher than the other pollutants, probably due to the high sulfur content of the sludge.

ALTERNATIVE DRYING PROCESSES

Fry-drying is a technique that provides a quick evaporation and a high humidity content. This process uses the process of “frying” for approximately 10 minutes in oil at 150°C. The sludge is molded in a pre-determined size, shape and thickness and placed in a conveyor belt submerged in oil. The velocity of the belt and the supplied amount of sludge is controlled by the system; therefore, the time of immersion is also controlled. The vapor generated that dragged oil generated during the process are then condensed, and passed through a separation process where the oil is collected and reused (Chae *et al.*, 2016).

Through this method the lower heating value heat value of the sludge was increased and the humidity levels were low, below 5% (Chae *et al.*, 2016).

Bennamoun *et al.* (2013) presents a study about the combination of air and solar drying. Those methods depend on the climate condition, as for example solar radiation and air temperature, and require energy between 30KWh and 200 kWh to evaporate one ton of water.

Solar heater can be used to heat the air supplied to the drying process of wastewater sludge. Moreover, other processes can be combined to provide pre-heated air (Tuncer *et al.*, 2020).

Mathioudakis *et al.* (2013) develop a system where solar concentrators are used to accelerate the evaporation rate of water taking advantage of the artificial greenhouse effect promoting non-equilibrium condition between the vapor pressures which is controlled by the inlet air. The main component of this process is where the wastewater sludge mixes with air. The humid air is removed from the mixture at a rate of 5,000 m³/h.

PROPERTIES OF WASTEWATER SLUDGE FROM DRYING PROCESSES

Avelar *et al.* (2018) reported that the drying process of a mixture of 75% sludge and 25% of eucalyptus bark using hot gases from a furnace at 0.64±0.02 m³/s and 100±20 °C, presented a better drying rate, which made the solid content to increase from 31% to 72%, during a period of 5h.

One of the advantages of using drying by heat compared to other drying processes is the improvement of biosolids, since drying by heat is the

good for production of biosolids of Class A, eliminating pathogens, including viruses (EPA, 2020).

Mathioudakis et al (2013) demonstrated in their research in Greece that due to water evaporation, the sludge reduced its volume significantly to 90%. The sludge cake became sludge granules with 10-15% reduction in humidity. The volatile fraction increased from 56.8-66.8% (w/w) of dry solid content. The level of fecal coliform was reduced three orders of magnitude, which demonstrated that the process also caused some level of sludge sanitization.

More studies are required to determine the physical-chemical properties, elementary composition, thermal behavior, composition and ash fusibility) of the material so it can be used in energy applications as reported by Virmond et al. (2012) about other fuels from biomass.

Batistella et al. (2015) reported some wastewater properties: lower heating value of 14.55 MJ/kg and higher heating value of 16.19 MJ/kg; composition of the dry material of 33.87% of carbon, 33.87% of hydrogen, 5.88% of nitrogen and 0.67% of sulfur.

CONCLUSION

The processes of pre-treatment are essential to make the energy recovery of the wastewater sludge possible.

We emphasize that the drying process has a huge impact on energy consumption of on the fuel production processes from wastewater sludge.

Drying processes using exhaust gases can be a viable alternative for energy recovery, however this possibility is little explored. Renewable energy sources, as solar energy for example, has the potential to be more widely used and increase the overall efficiency of the system.

After the drying process, the wastewater sludge showed to have high levels of sanitization, reducing the amount of pathogens. That is a positive, promising and extremely relevant result, specially in midst of the Coronavirus pandemics.

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