ANALYSIS OF DRYING TECHNOLOGIES FOR WASTE WATER TREATMENT PLANT SLUDGE AS AN ALTERNATIVE SOURCE OF ENERGY

Belzahet Treviño[(1)*], Jose Rodriguez[(2)],
(1,2) Center for Water Studies ITESM, Monterrey, Mexico
ITESM Campus Monterrey, Monterrey, N.L. México
btrevino@itesm.mx

SUMMARY

Wastewater treatment plant sludge (WWTPS) is used as a composting fertilizer or disposed of in landfills. Potential hazards related to the existence of pathogens and heavy metals along with the disposal cost, have made current applications less accepted. Recently, high-energy consumption industries have considered WWTPS as an alternative fuel. Basic requirements for WWTPS as a fuel are heating value (HV) and water content. Water content is an important factor due to the increase in transportation costs and a reduction in net energy value. Typical WWTPS have 80% water, and drying down to 10% is a must, for fuel purpose. The objective of this study was to analyze energy balance and feasibility of all commercially available WWTPS drying technologies. Energy demands for all dryers ranged from 0.95 to 1.1 KWH/kg evaporated water. Total drying energy demand was calculated and compared to the energy value of the dry sludge. Average drying energy was calculated at 2514.7 KWH/ton dry sludge. Anaerobic digested sludge energy value was measured at 2075.5 KWH/ton, while non-anaerobic digested sludge energy value was 3590.6 KWH/ton. Most facilities produce anaerobic digested sludge, since biogas is an attractive byproduct for electricity purposes. In this scenario, the production of dry sludge for alternative fuel is not feasible, since the net energy gain is negative. The only exception for this case represented the use of solar dryers and/or owned biogas for drying purposes. Solar dryers appeared to be the best drying option for the production of alternative fuel from WWTPS.

INTRODUCTION

Waste biosolids generation is currently an environmental and economical problem for many countries. The natural degradation of biosolids generates methane as a residue, which is considered one of the highest greenhouse effect compounds, responsible for global warming[1]. Problems associated with current applications are landfill cost, lack of biosolids, fertilizer market, and potential hazards related to the existence of pathogens and heavy metals[3].

On the other hand, many high energy consumption industries like cement, steel, glass, ceramic, and aluminum are currently looking for environmental cheap alternative sources of energy[4]. These industries depend mostly on fossil fuels (petroleum derivatives) such as natural gas and petroleum coke. The use of fossil fuels as a source of energy increases the amount of carbon dioxide (CO_2) in the atmosphere, affecting the greenhouse effect. Many of these industries are located in countries that belong to the Kyoto Protocol, and who are therefore looking to reduce greenhouse effect gases, including methane and carbon dioxide[5], [6].

The basic requirements for WWTPS as a source of energy in high energy consumption industries are heating value (HV) and water content. Water content is an important factor due to increase in transportation costs and reduction in net energy value for the sludge. The best type of biosolid for energy purpose is that which has the lowest water content (5 – 10 %), the highest heating value, and the shortest distance to the high energy consumption facility[8].

Typical water content on WWTPS is around 70 – 80 %, depending on the facility's dewatering system type. Filter band and filter press are some of the most common equipments used in wastewater treatment plants[10]. Unfortunately, these equipments do not meet the water requirements for sludge to be considered as an alternative source of energy. Most high-

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energy consumption industries need no more than 5 to 10 % of water in their solid fuel. The problem in removing the water from a WWTPS is the energy required in the drying process.

The Objective of our research is to evaluate all commercially available WWTPS drying technologies based on their energy requirements and feasibility

MATERIALS AND METHODS

Available data along with sampling from a local water utility company was used in order to perform the following methodology. The study begins with the selection of a wastewater treatment plant among three facilities. The selected wastewater treatment plant was analyzed, measuring and sampling sludge along the process. The selected sludge was evaluated for mass loss at different drying temperatures in order to obtain the maximum heating value with minimum water content. Commercially available drying technologies were evaluated according to the total energy requirement and sludge temperature. An average total energy requirement was calculated and compared to the minimum thermodynamic requirement. Heating values from dry digested and non-digested sludge were measured. The total amount of energy present in both types of sludge was compared to the total amount of energy needed for drying purposes. Different sludge and drying scenarios were evaluated in order to identify a feasible WWTPS alternative fuel process.

RESULTS AND DISCUSSION

Wastewater Treatment Plant Selection

Available wastewater treatment plants were analyzed for sludge type, sludge mass flow rate, and distance from main high energy consumption industries. The Dulces Nombres plant was selected based on its sludge production and sludge heating value (worst scenario).

Table 1. Wastewater Treatment Plants Characteristics

WWTP	SLUDGE Wet Sludge (80% water)	SLUDGE MASS FLOW (ton/day)	DISTANCE (km)
Dulces Nombres	Digested	352	40
Norte	Digested	142	25
Noreste	Non-digested	173	15
Cadereyta	Non-digested	40.7	40
Santiago	Non-digested	35.3	40

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Wastewater Treatment Plant Sludge Mass Balance

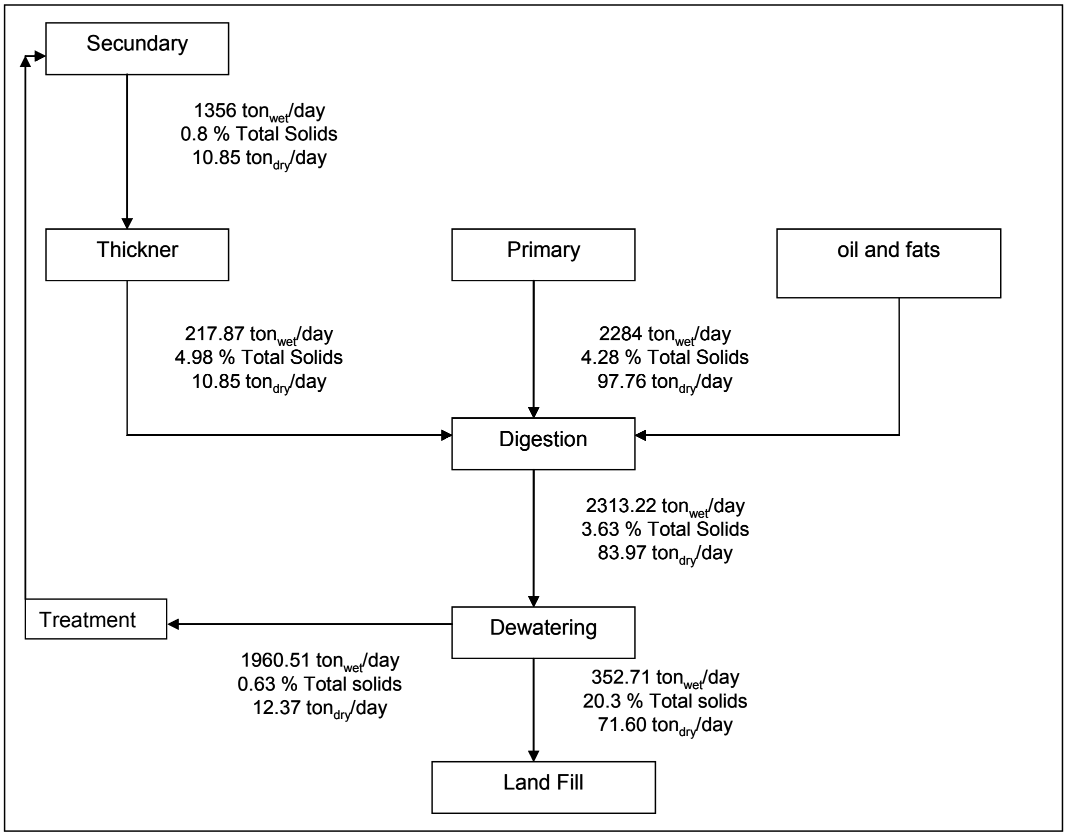

Figure 1. Wastewater treatment solids flow diagram

Sludge Analysis

Table 2. Sludge Analysis

SLUDGE	Water %	Solids Ton/Day	Organic Solids %	Inorganic Solids %	Heating Value kcal/kg dry base
Primary	95.72	97.76	60.98	39.02	2977
Secondary	99.20	10.85	70.00	30.00	4100
Thick	95.02	10.85	77.71	22.29	4100
*Non-digested	95.66	108.61	62.90	37.10	3090
Digested	96.37	83.97	56.75	43.25	2310
Dewatered	79.7	71.60	56.95	43.05	2310

* Obtained by mass balance

Figure 2 presents the sludge mass loss during drying at different temperatures. As we can see, between 50°C and 110°C, sludge mass loss is directly proportional to the drying temperature. We can assume that, at this stage (Stage1), the sludge is loosing most of its water content, and applied drying energy is being used for water evaporation purposes (latent heat). Between 110°C and 150°C, there is no correlation between sludge mass loss and temperature. We can assume at this stage (Stage 2) that sludge is getting sensible heat, therefore increasing its own temperature. Up tp 150 °C heating values were maintained at original levels. Between 150°C and 400°C, sludge mass loss is again directly proportional to the drying temperature, but with a lowest slope, compared to stage 1. Heating values are inversely proportional to heating temperature. We can assume at this stage (Stage 3) that sludge has gained enough activated energy to initiate combustion. When the sample reaches 400 °C, all organic material has burned.

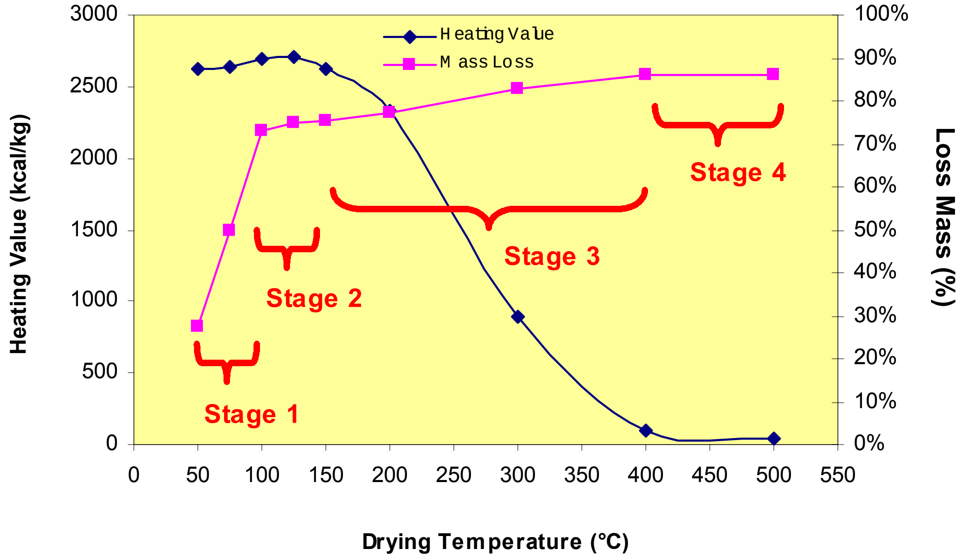

Figure 2. Sludge loss mass at different drying temperatures

Sludge Drying Technologies Analysis

The minimum thermodynamic requirement for sludge drying was calculated based on the sensible and latent heat necessary to evaporate water present in the sludge.

Table 3. Commercially available Drying Technologies and Energy Requirements

DRYING TECHNOLOGY	MAIN HEAT TRANSFER MECHANISM	SLUDGE TEMP. °C	THERMAL ENERGY KWH/L	ELECTRICAL ENERGY KWH/L	TOTAL ENERGY KWH/L
Flash Dryer[14]	Convection	96	0.99	0.06	1.05
Fluidized Bed[15]	Convection	NA	1.07	0.03	1.10
Rotary Dryer[16]	Convection	90	0.95	0.10	1.05
Band Dryer[17]	Convection	65	0.80	0.02	0.82
Drum Dryer[18], [19]	Conduction	115	0.92	0.15	1.07
Paddle Dryer[20], [21] ,[22]	Conduction	115	0.90	0.05	0.95
Green House Dryer[23], [24]	Radiation	40	1.51	0.02	1.53
Min.Thermodynamic			0.71		

"NA" Not Available

Feasibility Analysis for Drying Technologies

Wastewater treatment plants have different options for sludge management, as presented in Figure 3. Starting with 1 ton of non-digested sludge (dry basis) for all scenarios, we present the energy feasibility analysis for each one.

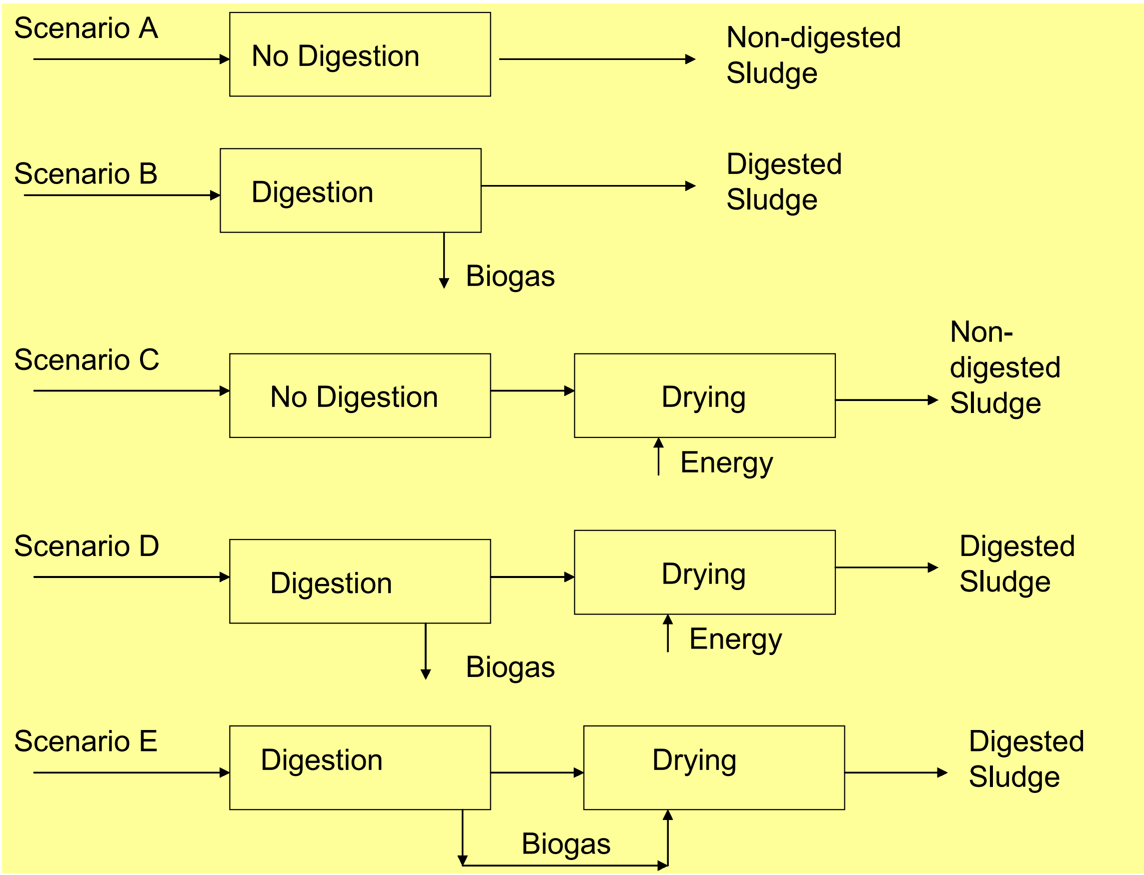

Figure 3. Different feasibility scenarios for WWTPS management

Table 4. Sludge management energy scenarios

SCENARIO	SLUDGE WATER %	AVAILABLE BIOGAS KWH/ton	SLUDGE ENERGY KWH/ton	EXTERNAL DRYING ENERGY KWH/ton	NET ALTERNATIVE FUEL KWH/ton
A	80	0	3590.6	0	0
B	80	1218.2	2075.5	0	1218.2
C	10	0	3590.6	2514.7	1075.9
D	10	1218.2	2075.5	2514.7	779.0
E	10	0	2075.5	1296.2	779.0
D*	10	1218.2	2075.5	0	3294.0

Based on 1 ton of Solids

CONCLUSIONS

WWTPS could become a vital part of developing a sustainable renewable source of energy for high energy consumption industries. On the other hand, the application of WWTPS as an energy source solves all risk problems associated with its current use as a fertilizer and in land farming. The application of WWTPS as an energy source in multinational industries (Kyoto Protocol) will allow them to use the CO_2 credits in other countries that exceed in greenhouse effect gas emissions. WWTPS from an activated sludge biological treatment generates a different type of sludge. Non-digested dewatered and digested dewatered sludge are the most appropriate sludge for alternative fuel purposes. Non- digested dewatered sludge has a much higher heating value (4100 kcal/kg dry base) compared with the digested heating value (2310 kcal/kg dry base), therefore, it is much more attractive for fuel purposes. In any of the two sludge scenarios, both have to be dried in order to be considered as alternative fuels. Most large wastewater treatment plants prefer having anaerobic digestion of sludge in order to produce biogas for drying requirements or power (electricity). Biogas from sludge digestion could be enough for the drying requirements, but this option will reduce the sludge heating value to a non-attractive level for fuel applications. On the other hand, the use of external energy for drying requirements reduces the overall net available energy to 779 and 1075 KWH/ton for digested and non-digested sludge, respectively. A more attractive alternative for sludge drying is the application of solar drying, where the need for fossil or biogas external energy is cero. This scenario produces a 2075 and 3590 KWH/ton for digested and non-digested sludge, respectively, with no need for biogas or fossil fuel external energy for drying. The use of WWTPS as an alternative source of renewable energy, along with the solar drying technologies for drying purposes, could impact the sustainability of high energy demanding industries in a very positive way.

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