Analysis of Drying Technologies for Wastewater Treatment Plant Sludge as an Alternative Source of Energy

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Abstract
Wastewater treatment plant sludge (WWTPS) is used as fertilizer or disposed 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 fuel are heating value and water content. Typical WWTPS have 80% water, and drying down to 10% is required for fuel purpose. The objective of this study was to analyze energy balance and feasibility of commercially available WWTPS dryers. Energy demands for all dryers ranged from 0.82 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 2514.70 kWh /ton dry sludge. Anaerobic digested sludge energy value was measured at 2075.50 kWh/ton, while non-anaerobic digested sludge was 3590.60 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. Solar dryers appeared to be the best drying option for the production of alternative fuel from WWTPS.

Keywords
Wastewater Sludge, Alternative Fuel, Energy, Drying Technologies.

1. 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 (Basta and Sloan, 1999).

Problems associated with current sludge applications are landfill cost, lack of biosolids fertilizer market, and potential hazards related to the existence of pathogens and heavy metals (International Aluminum Institute, 2003). 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 (Blankinship, 2003). 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 (CO2) 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 (Goldstein, 2003), (Bomprezzi et al., 2002).

The basic requirements for Wastewater treatment plant sludge (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 (Oleszkiewicz and Mavinic, 2001).

Typical water content on WWTPS is around 70 – 80 %, depending on the facility's dewatering system. Filter band and filter press are some of the most common equipments used in wastewater treatment plants (H&P Renneburg Division, 2004). Unfortunately, these equipments do not meet the water requirements for sludge to be considered as an alternative source of energy. Most high-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.

2. 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 and heating values 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 heating 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.

3. Results and Discussion

3.1 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).

3.2 Wastewater Treatment Plant Sludge Mass Balance

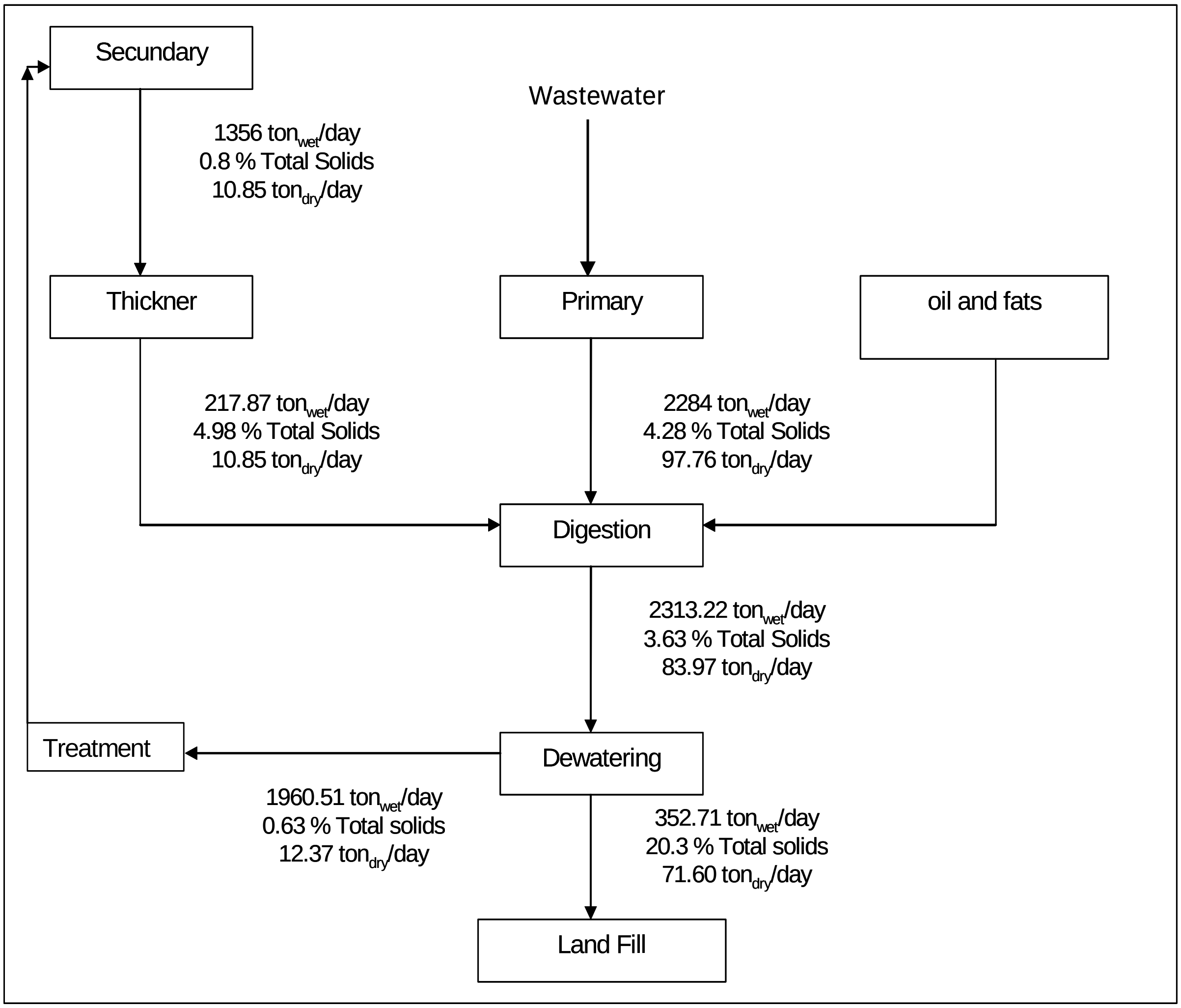

Figure 1: Wastewater treatment solids flow diagram

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

3.2 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.

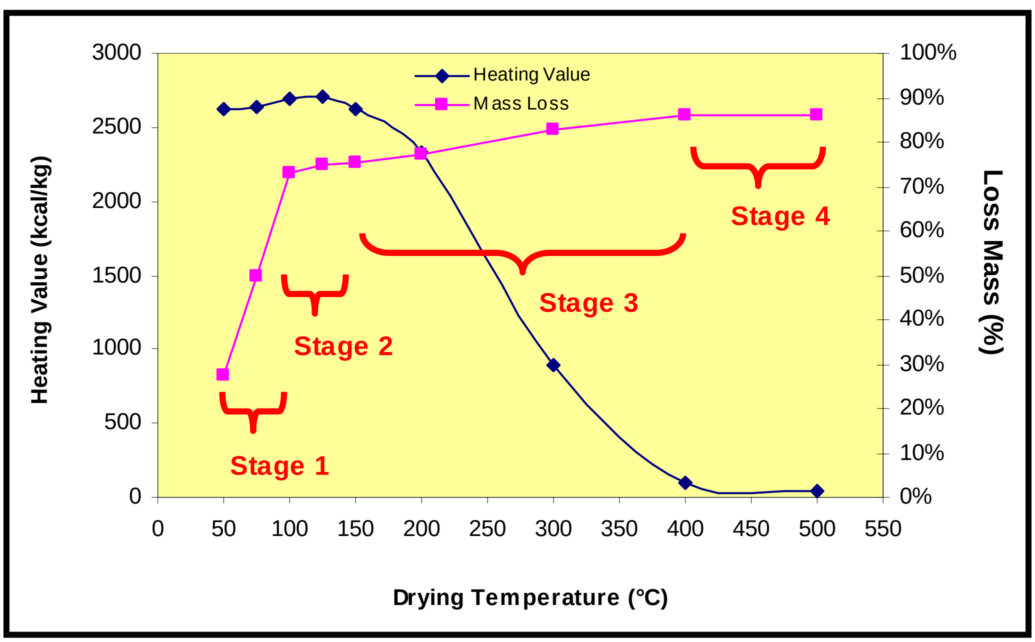

Figure 2: Sludge loss mass at different drying temperatures

3.3 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 (Crown Milling Flash Dryers, 2004)	Convection	96	0.99	0.06	1.05
Fluid Bed (H&P Renneburg Division, 2004)	Convection	NA	1.07	0.03	1.10
Rotary (Grontmij Vandenbroek Int., 2004)	Convection	90	0.95	0.10	1.05
Band (STC, 2004)	Convection	65	0.80	0.02	0.82
Drum (Simon Dryers, 2004)	Conduction	115	0.92	0.15	1.07
Paddle (Komline-Sanderson, 2004)	Conduction	115	0.90	0.05	0.95
Greenhouse (Parkson Corporation, 2004)	Radiation	40	1.51	0.02	1.53
Minimum Thermodynamic.	---	---	0.71	---	---

"NA" Not Available

3.4 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.

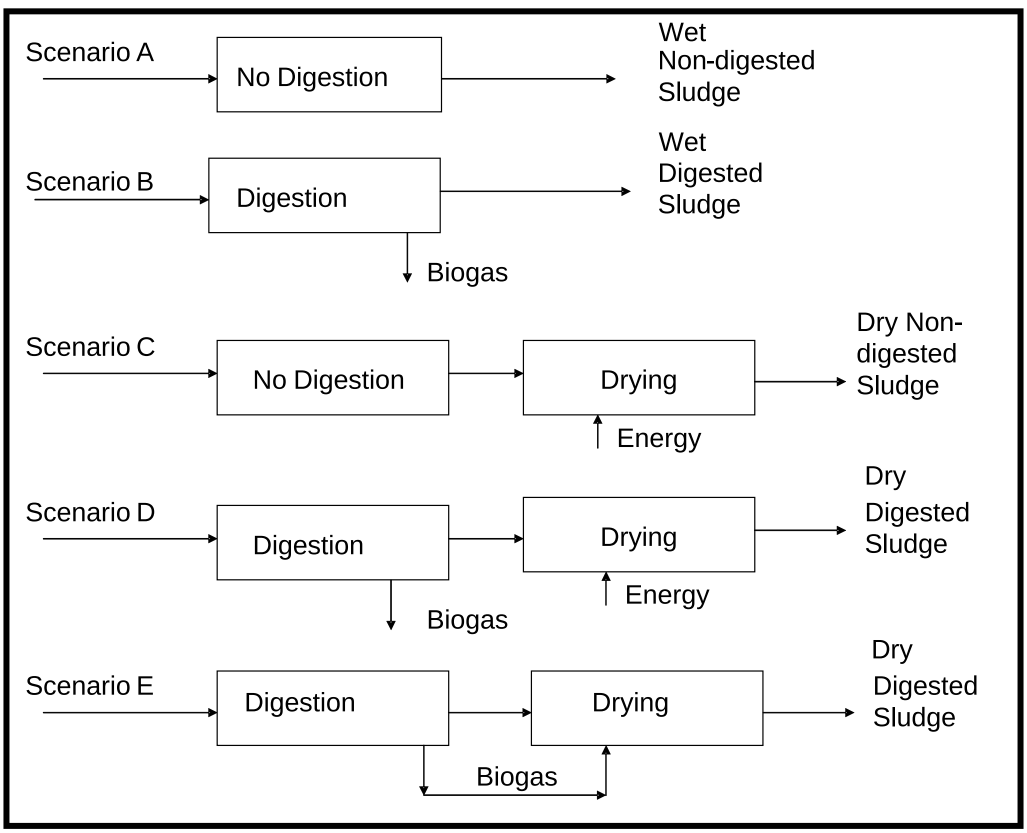

Figure 3: Different feasibility scenarios for WWTPS management

Table 4: Sludge management energy scenarios based on 1 ton of Solids

Scenario	Sludge Water %	Available Biogas kWh/ton	Sludge Energy kWh/ton	Fossil 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

* Solar Drying

4. 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 CO2 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 used 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 alternative available energy to 779 and 1075.9 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 2075.5 and 3590.6 kWh/ton for digested and non-digested sludge, respectively, with no need for biogas or fossil fuel drying energy. 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.

References

Basta, N.T. and Sloan J.J. (1999), "Heavy metals in the environment". *Journal of Environmental Quality*, Vol. 28, No. 2, pp 633-638.

Blankinship, S. (2003). "Reported greenhouse gas reductions increased in 2001". *Power Engineering*, Vol. 107, No. 4.

Bomprezzi, L., Pierpaoli, P. and Raffaelli, R. (2002). "The heating value of gas from biomass gasification: a new method for its calculation or prediction", *Proceedings of the Institution of Mechanical Engineers. Part A. Journal of Power & Energy*, Vol. 216, No. 6, pp 447-452.

Crown Milling Flash Dryers. (2004). Milling Flash Dryers, http://www.europacrown.com/prodprin/millflash.htm . 04/01/04.

Goldstein, J. (2003). "What's happening in biomass to renewable energy", *BioCycle, Journal of Composting & Organics Recycling.* Vol. 44, No. 9, pp 75.

Grontmij Vandenbroek International. (2004). VADEB Systems - Sludge Drying - Rotary Dryers, http://www.vadeb.nl/system2.htm . 04/03/04.

H&P Renneburg Division. (2004). Fluid Bed Dryers & Cooler, http://www.heylpatterson.com/Products/FluidBedren.asp . 04/05/04.

International Aluminum Institute. (2003). "Aluminum sector releases new greenhouse gas calculation tool", *Pollution Engineering*, Vol. 35, No. 7.

Komline - Sanderson. (2004). Paddle Dryer / Processor, http://www.komline.com/Products_Services/Thermal/PaddleDryerProcessor.html . 04/07/04.

Oleszkiewicz, J.A. and Mavinic, D.S., (2001), "Wastewater biosolids: an overview of processing, treatment and management", *Canadian Journal of Civil Engineering*, Vol. 28, No. 1, pp 102-114.

Parkson Corporation. (2004). Thermo-system solar dryer, http://www.parkson.com/thermo.htm . 04/11/04.

Simon Dryers. (2004). Drum Dryers, http://www.simon-dryers.co.uk/drum/index.htm . 04/14/04.

STC. (2004). Sludge heat drying system - Band Dryer, http://www.stcsa.es . 04/16/04.

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