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The biodrying concept: An innovative technology creating energy from sewage sludge

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HIGHLIGHTS

- Fullscale biodrying installation treating 150 kton of sludge per year.
- Generation of energy (9.3 MW) from sewage sludge.
- Recovery of ammonium sulphate solution 40% (w/w) (7.3 kton/year) from process air.
- Total wet sludge weight reduction by 73%.
- 80% Odour reduction due to a biobed.

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ABSTRACT

A full-scale biodrying installation was treating 150 kton (wet weight) of dewatered waste activated sludge per year. The waste was treated at thermophilic conditions (65–75 °C) in a 2-step forced aeration process reducing the total wet sludge weight by 73%. The final product had a high caloric value (7700–10,400 (kJ/kg)), allowing a combustion for energy generation in external facilities. The resulting product met the European microbial and heavy metal quality standards needed for an application as organic fertilizer. The facility used <0.5 MW of electricity and recovered 9.3 MW from biologically produced heat, which was internally used for the heating of office buildings. Produced ammonia, originating from the microbial conversion of organic matter, was recovered from the ventilated air in an acid gas scrubber as an ammonium sulphate solution 40% (w/w) (7.3 kton/year) and was sold as substitute for artificial fertilizers. The sustainability of this process is discussed relative to other sludge handling processes.

1. Introduction

During wastewater treatment circa 40% of the biologically removed organic carbon is converted to biomass (sludge). This excess sludge is an unwanted by-product and presents rising challenges since it accounts for about half of the total cost of a wastewater treatment plant (Davis and Hall, 1997). Technologies such as landfilling, incineration, oxidization and digestion with hydrolysis are used to reduce sludge after (Wei et al., 2003) or before sludge thickening (Müller, 2000). A commonly used technology to handle organic waste is biological composting, which stabilizes organic matter to an almost odour and pathogen free humus, which can be beneficially applied to land (Mote and Griffis, 1982). During this composting process bacteria, actinomycetes, fungi, molds, and yeast oxidise long and short chain fatty acids, paper products, other pollutants and produce heat leading to an reduction of waste due to microbial conversion and water evaporation (Tuomela et al., 2000). Protozoa help to consume bacteria, and fungi, whereas rotifiers control the growth of the bacteria and protozoa hence minimizing the health related risks associated with pathogens (Haug, 1993). Composting aims for the maximal conversion of organic material. Therefore, water is added to the process when the organic matrix reaches certain dryness in order to preserve moisture for optimal microbial activity and hence maximal organic conversion. As a consequence, long residence times of circa 50 days are required, which is less practical for large quantities of sludge. Composting has significant uncertainties since it is increasing the dry solid content due the water evaporation by biologically produced heat, while decreasing the caloric value of mixed sludge to values, which are critical for an economically attractive combustion (Cai et al., 2013). Due to stringent EU-guidelines sludge usually cannot be applied on land and

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henceforth the sludge must be incinerated for which a dry solid content of 45% (w/w) or more is needed to gain energy from the combustion, which is typically not attained by sludge composting (Kudra et al., 2002). Other techniques such as thermal drying or direct combustion do not rely on microbial produced heat. Instead external energy needs to be supplied to evaporate water leading to high costs. A new technology, which is based on a similar process as composting, is the biodrying concept. The eventual goal of this concept is different from the conventional composting process and does not aim towards a complete mineralization of the waste (Tambone et al., 2011). Instead the metabolic heat is used to remove water from the waste matrix at the lowest possible residence time and minimal biodegradation hence preserving most of the gross calorific value of the waste matrix. During this process the organic matrix is both: substrate for microorganisms (which produce heat for drying) and the end product. The end product (fuel/granules) contains a high energy value and can be used as a replacement of coal and for thermal energy generation. This principle has been described for municipal waste and is often referred to as mechanical biological treatment (MBT) (Velis et al., 2009; Ofori-Boateng et al., 2013) but it is not well recognized for excess sludge treatment. Bio-drying of sludge can (in contrast to landfilling) reduce fossil fuel requirements and henceforth greenhouse gas emissions if combusted to produce steam and or power henceforth positively contributing to prevent climate change (Navaee-Ardeh et al., 2006; Rada et al., 2009b). Within the biodrying concept waste is reduced and recycled making this technology not only renewable but also sustainable. Research on biodrying is mainly applied for other waste resources than sludge and experiments are mainly conducted on laboratory based or small scale installation (Roy et al., 2006; Rada et al., 2009b). Full-scale biodrying installations are mainly applied for general waste and scientific papers reporting the results from a full-scale sludge biodrying plant are sparse (Frei et al., 2006). Since the European Union targets a reduction of waste disposal by 50% by 2050, technologies realizing a reduction of waste is a hot topic (Lundin et al., 2004). The capacity of a successfully running full-scale biodrying installation is presented in this study. The plant treats excess sludge and is compared with other sludge handling processes in order to evaluate its feasibility.

2. Methods

2.1. Process description

The biodrying facility in Zutphen, The Netherlands (coordinates 52.160915 N, 6.195345 W http://maps.google.nl/maps) is treating approximately 150 ktons of dewatered sewage sludge per year. The sludge origin is mainly from municipal and a small proportion from industrial wastewater treatment plants (secondary, un- and digestion sludge) with an average total solid content of 25% and with an organic fraction of 65%. The company (GMB) also has a second biodrying plant in Tiel, the Netherlands, treating 80 ktons sludge per year. Only the results of the plant in Zutphen are presented in this paper, more information can be found under (http://www.gmb-international.eu/Tunnel-composting-plants.aspx?GB-1-342). The sludge is delivered by trucks from different wastewater treatment plants from the Netherlands. The plant in Zutphen operates since 1981 and the optimized process is presented in this paper. Prior to the drying process, the sludge is mixed with the coarse fraction of already pre-dried sludge. The mixing of sludge aims the inoculation of the microbial population, which are well adapted for aerobic decomposition of organic matter at thermophilic conditions (65–75 °C). The mixed sludge with a dry solid content of 45% is then loaded by wheel loaders into drying tunnels of 1900 m^3 each. In addition, 5.6% (w/w) of woodchips are included to the process as structure material to allow a good aeration of the sludge during composting. After sealing the tunnels the sludge is aerated by blowing air through specially designed aeration shafts (spigots) integrated in the concrete floor. The process air was treated for odour control, heat and nitrogen recovery (see Section 2.4). The air needed for the evaporation of water as well as for the microbial activity was monitored and controlled online (Section 2.2). In total 25 tunnels are operated in different sequences to effectively reuse the heat within the process. Usually 22 tunnels are used for the first drying batch lasting 10 days. Ideally only two tunnels (for re- and unloading) are open at the same time while the remaining 20 tunnels are closed for drying of the sludge. After the first drying batch (10 days) the sludge is taken out of the tunnels and screened. The coarse fraction is used to mix it with fresh sludge and the fine fraction is brought to the second drying step (batch one) for further drying. Three tunnels are used for a second drying step (batch two) lasting 14 days. Therefore batch one (10 days) and batch two (14 days) are separated by time and space. The dried sludge from the second batch is unloaded by wheel loaders and transferred to a drum screen. The coarse fraction is recycled back to the pre-composting mixture preparation. The fine fraction is the final product and is expedited to external combustion plants for energy generation (Fig. 1).

2.2. Air management among tunnels

The biodrying tunnels are clustered and each cluster consists of three tunnels. These tunnels are connected to each other by air ducts which are mounted on top of the tunnels. The first tunnel takes in fresh air. This tunnel is at the end of the biodrying procedure of batch on and hence contains warm dried sludge that needs to be cooled down. The air is heated and discharged to the second tunnel where it is used to dry the sludge. This tunnel discharges the hot air to the third tunnel where the fresh sludge mixture needs to be heated to start the composting process. By using the air three times the air flow to be cleaned remains as low as possible and odorous components are partly broken down in the biodrying process. The first biodrying batch takes approximately 10–12 days. Before a tunnel is opened the material is cooled down and inactivated by fresh air (as mentioned above). The dried sludge from the first batch is mixed with pre-dried material (see Section 2.1) and transported by wheel loaders to an empty tunnel to start the second batch. In the second batch tunnels are identical to the tunnels for the first batch, only the air supply is different. A small part of the air of the first drying batch is used for the second drying batch. This air is already hot, saturated with water and contains enough oxygen for fast activation of the microbiological process. The second drying batch also acts as a biofilter and was operated for circa 2 weeks until achieving a dry matter content of 65–70%. The end product is cooled with fresh air and the tunnel is emptied by wheel loaders.

2.3. Temperature control within one tunnel

To achieve optimal evaporation and microbial activity, the tunnels are operated in four stages (I-IV) repeated in two batches one lasting 10 days and a second lasting 14 days per step. Batch one and two are occurring in different tunnels (Section 2.2). The temperature is automatically monitored during the whole process. For both batches the preheating of stage I is accelerated by using air of neighbour tunnels (incoming air has a temperature of 60 °C) thus reaching temperatures of 65–75 °C within the tunnel/the outgoing air, in 10–15 h (Section 2.2; Fig. 2). Warm air contains a higher drying capacity and can hence carry more water. Therefore the

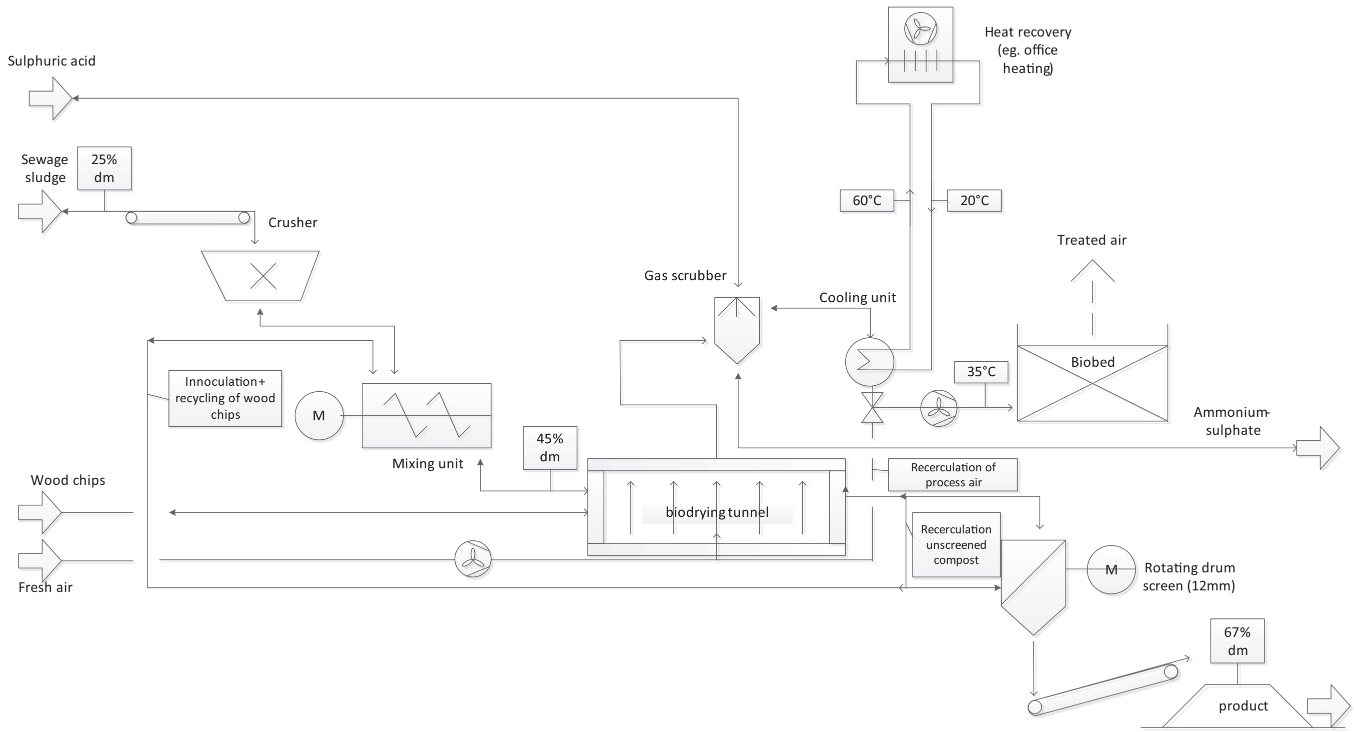

Fig. 1. Process flow diagram visualizing the bio drying process including: mechanical treatment of sludge, drying tunnels, air ventilation system, heat exchanger for heat recovery and gas scrubber for nitrogen recovery as well as the bio-bed filter for odour control.

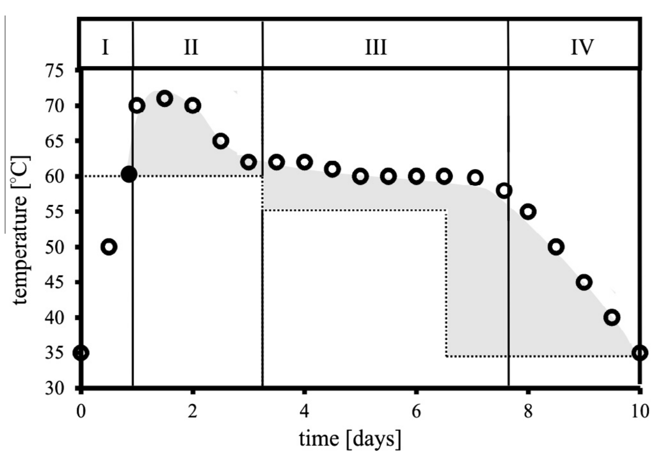

Fig. 2. Biodrying of sludge with four stages: (I) warming up of the sludge for 10–15 h until 70 °C (II) sanitation of sludge for 2 days at 65–70 °C (II) drying of sludge for 5 days and (III) cooling of process air to 35 °C. The dotted line (o) represents the out going air. The dashed line represented the temperature of the incoming air, which can be summarized in 3 phases (1) warming up of the tunnel with warm process air (60 °C) from an active tunnel (2) controlling the incoming air with 55 °C warm air from neighbour tunnel (being in phase II or III) and (3) cooling off with fresh air. After 1 day the ΔT between the incoming heat and biologically produced heat becomes positive and water can evaporate (grey area) and hence be removed from the system, by which the sludge is dried.

evaporated water can be only be removed from the tunnel if the ingoing air is colder than the outgoing air. The drying capacity of air was determined by calculating the saturation pressure of water vapour using the Goff Gratch equation and the ideal gas law (Goff and Gratch, 1946; Keener et al., 1997). In stage II the temperature in the tunnels is kept at 65 °C for 1–2 days aiming a reduction of pathogens. In stage III (of both batches) the temperature of the incoming air is held at 55 °C reaching temperatures in the tunnels of 60 °C due to microbial activity for 5 days (batch 1) and 9 days (batch 2), respectively. During aeration microorganisms produce heat while breaking down organic matter resulting in evaporation of water hence leading to a volume reduction of sludge. In stage IV fresh air is directed into the tunnels to cool down and inactivate the composting mixture until 35 °C (Fig. 2). Due to cooling of the saturated process air a condensate was formed, which was directed to the wastewater treatment plant for further treatment.

2.4. Heat and nitrogen recovery as well as odour control

Microbial produced heat was effectively captured by heat exchangers and was reused to heat office buildings. No external heat is required in the process. For the cooling unit effluent from the nearby waste water treatment plant was used. During biological conversions ammonium was generated which is transferred to the gas phase. The ammonia rich process air was treated in an acid gas scrubbing unit operated at 70 °C, where ammonia is chemically bond to sulphuric acid hence producing ammonium sulphate solution. A part of the total ammonia load was discharged to the wastewater treatment plant until allowed threshold values, yielding in a varying nitrogen removal efficiency of circa 60–80%. Process air was not only recycled for heat recovery but also for the purpose of minimizing the required volumetric capacity of the biofilter needed for the odour treatment of volatile organic compounds. The biofilter bed was filled with tree bark chips and operated at a volumetric load of 125 (m^3 air/m^2 /h). Odour reduction was quantified according to NEN-EN 13725, which is a standardized quality determination of odour concentration by dynamic olfactometry.

2.5. Quality assessment of sludge

In order to apply the dried sludge on agricultural land the European regulation for pathogen control and heavy metal contents need to be met. In case of the microbial assessment the reduction of spores is not a prerequisite; however the reduction of pathogens is required (Kelessidis and Stasinakis, 2012). Therefore the removal of pathogens was measured using a standardized protocol for pathogen reduction measurements NTA8777:2011. The sludge was spiked with *Enterococcus faecalis*, and the number of colony forming units was determined before and after treatment in the tunnels at 62.5 °C for 24 h. Additionally, the final product from the biodrying tunnels was tested for the indicator organisms *Escherichia coli* and *Salmonella Senftenberg* (775 W, H_2S negative).

Furthermore the content of the heavy metals cadmium, chrome, copper, lead, nickel and zinc was measured according to the NEN 6966/C1 as well as Quicksilver according the NEN-ISO 16772 guidelines. The caloric value of the dried sludge of 20 samples was determined according DIN EN 15170.

3. Results and discussion

3.1. Operation biodrying tunnels

Biodrying is an economical and energy-saving method to reduce the sludge content and to evaporate bound water by biologically produced heat hence producing an end product readily applicable for further incineration (Dufour, 2006). It has been already described earlier that due to forced aeration water evaporation is greater than water generation leading to a volume reduction and higher dry content (Cai et al., 2012). In this study the data, of a successfully operating biodrying installation running since 1981, are presented. The process reduces the mass of sludge by 73% and hence the cost associated with the treatment of sludge. The end product had a dry solid content of 67% (w/w) and was reused for power generation in coal fired power plants (Table 1). The operation of the biodrying tunnels consisted of 2 batches one lasting for 10 and a second lasting for 14 days. Each batch was operated in four stages and a typical temperature profile of batch 1 is shown in Fig. 2. In stage I of both batches sludge was preheated. During the first hours the incoming air is warmer (60 °C) than the outgoing air (circa 35 °C). Since the drying capacity of cold air is lower than for warm air water will in fact condense in the tunnel (Table 1). Due to the warm incoming air, subsequent condensation of water and heat transfer the microbiology gets active and starts producing heat by which the temperature in the tunnel will raise leading to a higher temperature of the outgoing air than the incoming air (Fig. 2). Due to temperature difference between the incoming heat and the microbial produced heat water will evaporate. Evaporation of water hence occurs from stage II on, during which the drying capacity of the incoming 60 °C warm air was 130 (gwater/m^3 air) and the drying capacity of 70 °C warm outgoing air was 270 (gwater/m^3 air) leading to a transportation of evaporated water out of the tunnel and hence to the a drying of sludge (Fig. 2). During stage II the temperatures of 65–70 °C will inactivate pathogens and hence also minimize the health related risks of the sludge. In stage III the incoming air was kept at 55 °C (corresponding to a drying capacity of 103 (g water/m^3air)) leading to a temperature of the outgoing air of 60 °C due to microbial produced heat (Fig. 2; Table 1). During the whole process microorganisms oxidized 9.2 ktons of TSS per year and generated heat by which 102 kton of water were evaporated, leading to a net mass reduction of 111 ktons sludge per year (73% mass reduction). Before discharging the sludge from the tunnel the mixture was cooled down in the last fourth (IV) stage to 35 °C (Fig. 2). The final sludge had a solid content of 67% and caloric value of 7700–10,400 (kJ/kg) (Tables 1 and 3). An additional positive attribute of the biodrying concept is that operational efforts are fairly simple. Therefore, no higher educated personnel is needed and maintenance and repair procedures can be easily overlooked.

Table 1
Biomass reduction, process air handling as well as heat and nitrogen recovery.

Parameters	Unit	Data
Reduction		
Sludge load inflow	(kton/year)	150
Dry matter inflow	(%)	25
Dry matter outflow first batch	(%)	55
Sludge outflow	(kton/year)	39
Dry matter outflow second batch	(%)	67
Mass reduction of sludge	(%)	73
TSS reduction	(kton/year)	9.2
TSS reduction	(%)	26
Water reduction	(kton/year)	102
Presence of *E. coli* in final product	(cfu*/g)	<10
Presence of S. Senftenberg in final product	(cfu*/25 g)	Not detected
E. faecalis reduction after biodrying	(cfu*/g)	5.56 log units
Odour reduction	(%)	80
Nitrogen recovery (gas)		
Consumption H_2SO_4 (96%)	(kg H_2SO_4/ton sludge)	15
$(NH_4)_2SO_4$ (40% (v/v))	(kton/year)	7.3
Process air / heat recovery		
Treated air through biofilter	(m^3/year)	2.342 × 106
Drying capacity air at 35 °C	(gwater/m^3air)	36
Drying capacity air at 55 °C	(gwater/m^3air)	100
Drying capacity air at 60 °C	(gwater/m3air)	130
Drying capacity air at 70 °C	(gwater/m^3air)	270
Capacity heat exchanger	(MW)	9.3

* colony forming units (cfu).

3.2. Air treatment: nutrient and heat recovery and odour treatment

Effective air management is a crucial component of the biodrying concept since it is not only needed to dry the sludge, but also to treat the air for odour control and to recover heat and nitrogen from ammonia present in the process air. Within this process 7.3 ktons of 40% (v/v) ammonium sulphate solution were recovered from ammonia released during to the conversion of organic matter (Table 2). In a gas scrubbing unit, ammonia was chemically bound in a sulphuric acid solution. A small part of the total ammonia load was discharged to the wastewater treatment plant however most of the nitrogen was recovered in form of a 40% (v/v) ammonium sulphate solution (7.3 ktons/year) (Table 1). The recovery of nutrients from sludge is worldwide a common practise and mostly ammonium is recovered as magnesiumammoniumphosphate (MAP). However, the recovery of ammonium sulphate from the process air is barely applied and no literature was found reporting an effective full-scale biological ammonium recycling technology (Dichtl et al., 2007). Due to the high quality of the ammonium sulphate it can be readily applied for agriculture purpose as a sulphur and nitrogen fertilizer henceforth reducing internal costs of the biodrying installation.

The harassment of odour emissions to the general public is a serious issue, which can lead to legislative penalties. An odour

Table 2
Metal composition of dried sludge and threshold values demanded by the EU sludge directive EU 86/278 and the Dutch frame work (BOOM) for the utilization of sludge in the agricultural sector.

Compound	This study (mg/kg)	EU 86/278 (mg/kg)	BOOM (mg/kg)
Cd	1.8–1.9	20–40	1.25
Cu	480–510	1000–1750	75
Hg	1–1.1	16–25	0.75
Ni	30–32	300–400	30–75
Pb	94–130	750–1200	50–300
Zn	120–1400	2500–4000	150–300

Table 3
Resource requirements of different drying technologies.

Parameter	Unit*	1	2	3 (this study)	4	5
CO2 emission	Kg/ton	83	618	−153	6	−174
Electricity usage	MW	3.22	0.65	0.46	0.52	0.63
Natural gas usage	Nm^3/year	1533 × 103	61 × 103	–	4778 × 103	–
Fossile fuel usage	m^3/year	–	123	204	–	–
Steam use	ton/year	–	–	–	–	57,327

* *Note*: All scenarios (1–5) belong to one study and all calculations were based on a treatment capacity of 20,000 tons of dry solids per year with a beginning dry content of 30%. The study was conducted by the Dutch Foundation for Applied Water Research (STOWA, 2010 1. indirect drying, 2. wet oxidation, 3. biological drying (data from this biodrying plant), 4. direct thermal drying with gas, 5. indirect thermal drying with surplus heat.

reduction of 80% was achieved by directing the process air through the biofilter, consequently reducing the odour emission until levels which are in accordance with Dutch regulations. (Fig. 1, Table 1). Due to circulating the air three times internally the total volume of the process air was minimized to $2.342 \times 10^6\ m^3$/year, hence minimizing also the size of the biofilter. The air management benefitted also energy requirements of the installation. The biologically produced heat was not only used to efficiently evaporate the bound water from the sludge matrix but it was also recovered in a heat exchanger providing 9.3 MW of energy (corresponding to 2.9×10^9 MJ), which was used to heat office buildings (Table 1).

3.3. Microbial and chemical quality of the sludge

Despite the fact that the dried sludge of this plant was transported to incineration plants for energy generation and was hence not used for agricultural purposes, the quality of the dried sludge was assessed as well and the potential usage of sludge in the agricultural sector is discussed. Untreated sewage sludge usually contains high loads of pathogens and heavy metals, which would pose a risk to human health if applied on agricultural land. Pathogens are mostly mesophilic bacteria which are killed or considerably minimized during the pasteurisation step of the biodrying procedure (Fig. 2) (Navaee-Ardeh et al., 2010). The final product within this research complied with the microbial European and Dutch quality standards ((ABP) EU1069/2009 and EC 142/2011) meaning that the initial sanitation step (50–70 °C) was producing a product, which can safely be applied as fertilizer on land (Fig. 1, Table 1). These regulations demand a complete removal of *S. Senftenberg* (no detection in 25 g sample) a detection of *E. coli* to values lower than 1000 (cfu/g) and a minimal 5 log reduction of general pathogens such as *E. faecalis* (Table 1). The reduction of sporforming bacteria is not a requirement in these regulations and was hence not tested. Future End of Waste (EoW) regulations are still in progress (http://susproc.jrc.ec.europa.eu/activities/waste/). Within this regulations it is written that all animal by-products and/or sewage sludge need to be treated at ⩾65 °C for at least 5 days, ⩾60 °C for at least 7 days or ⩾55 °C for at least 14 days. The same criteria hold for anaerobic digestion. The process in this study hence complies with the microbial standards of current and future regulations (Fig. 1). All heavy metal concentrations of the final product (dried sludge) remained within the allowed threshold concentrations of the European Union (EU 86/278) needed for an application as fertilizer on agricultural land (Table 2). It must be mentioned that every country in the EU has its own threshold values and some are more stringent than others. A good review on different quality standards within the EU is given by (Kelessidis and Stasinakis, 2012). The Dutch regulations in specific are very rigid pushing sludge treatment plants such as presented here to burn the sludge rather than to apply it on land. Cadmium, copper and zinc exceeded the limits allowed by the Dutch quality standards (BOOM) (Table 2).

3.4. Comparison of the biodrying concept to other sludge reducing technologies

In order to evaluate the biological drying plant for energy efficiency the system was compared with 4 other sludge drying systems for gas, electricity, steam and fossil fuel requirements as well as for CO_2 emission (Table 3). Additional methods to dry sludge prior to combustion are for instance thermal drying with external heating energy, wet oxidation, or bio-physical drying (Mujumdar, 2004; Velis et al., 2009; Han et al., 2012). The technologies and the data gathering for the comparison of the different sludge drying techniques are explained elsewhere (STOWA, 2010). In contrast to other sludge drying methods the biodrying concept is more environmentally friendly and economical interesting, because it has the lowest electricity demand (0.46 MW) and does not require any steam or gas (Table 3). Although the biodrying technology uses 204 m^3 of diesel per year the combustion of biologically dried sludge has a negative (−153 $kgCO_2$/ton) CO_2 emission balance. Burning of biologically dried sludge is decreasing fossil fuel demands (e.g., coal) thus preventing additional atmospheric input of CO_2, whereas burning of coal jeopardizes our fossil fuels resources and pollutes our atmosphere with surplus CO_2 emissions (Table 4) (Lundin et al., 2000).

Due to the fast drying procedure (24 days) and high dry matter content (67%) the caloric value of the sludge remained between 7700–10,400 kJ/kg hence preserving the quality needed for the combustion of sludge (Fig. 2, Tables 1 and 4). This caloric value is in line with other dried sludge pellets and is close to the heating value of brown coal hence offering an attractive brown coal replacement, however not a replacement of anthracite coal which has a 3-fold higher burning value than the end product of this study. The dried sludge of this study had a comparable caloric value than the end product of MSW (Table 4). The demand to incinerate municipal solid waste (MSW) is increasing. For instance is Beijing investing into waste incineration since the region ran out of landfilling capacity (Wang and Wang, 2013). Also Ghana and Germany, see the incineration of MSW as attractive option for a

Table 4
Caloric value of different compounds.

Compound	LHV,ar [kJ/kg]	HHV,ar [kJ/kg]	Reference
Biodried sludge (this study)	7700	10,400	–
Biomass pellets	9500	10,450	(KEMA, 1999)
Sewage sludge dried (Thermal)	12,500	13,585	(EPON and KEMA, 2000)
Municipal waste with plastic	12,300	14,000	(Venendaal, 1994)
Brown coal	10,100	11,900	(Hein, 1994)
Anthracite coal	33,200	33,900	(van Doorn et al., 1996)

Low heating value (LHV); High heating value (HHV); as received (ar).

CO_2 reducing energy generation strategy (Ofori-Boateng et al., 2013) (Table 4). MSW contains a fraction of organic material, which is decreasing the caloric value due to high water contents. For this reason a similar approach than the here presented biodrying concept is used within these plants to increase the burning value of the total end product. This so called mechanical biological treatment (MBT) of the organic waste fraction is also used to decrease the water content of the organic waste matrix in order to increase the caloric burning value (Rada et al., 2009a). The biodrying concept offers hence an interesting alternative for the energy production from dried sewage sludge and other organic waste resources. Although, there is a clear trend in the European member states to an incineration of waste it must be emphasised that the first choice in hierarchy of European Environmental Policy is the reuse of waste, while incineration is the second (Decision 2001/118/EC, Directive 2008/98/EC). The assessment of microbial and chemical parameters of the sludge remains therefore interesting and a shift from incineration of sludge to agricultural usage might gain more popularity. The here presented installation shows a robust conversion of biomass into a high value product hence demonstrating that more research on this technology is appealing to gain more knowledge in order to improve our understanding of this technological concept.

4. Conclusion

This study presents the data of a sludge biodrying plant reducing the total sludge weight by 73% hence decreasing costs associated with transport and treatment of sludge. Several internally generated resources were reused and recycled. In the facility 9.3 MW heat and 7.3 kton of a 40% (v/v) ammonium sulphate solution were recovered per year. The final product had a high caloric value hence offering a good replacement for brown coal and met the European microbial and heavy metal quality standards needed for an application as organic fertilizer. This process creates a mindset that sludge can be seen as resource rather than simply as waste.

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