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Review paper

THERMAL TREATMENT OF SEWAGE SLUDGE PYROLYSIS AND GASIFICATION

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Abstract

The treatment of sewage sludge and, at the same time, a great demand for energy for heating and electricity production is a problem of modern society. The technology of modern times makes it possible to satisfy two needs at the same time. The first problem is the treatment of sewage sludge, sewage sludge disposal and environmental pollution. Another problem is the necessity to replace fossil fuels with alternative fuels in power plants and heating plants. Sewage sludge can be disposed of in several ways. The most effective treatment is thermal. The thermal treatment neutralizes harmful substances from the sludge and at the same time produces heat. The burning of sludge can be made in the rotary kilns, reactors for the pyrolysis and gasification.

Key words: *Gasification, pyrolysis, sewage sludge, energy.*

Introduction

In order to prevent global warming, the use of biomass as a new energy is promoted. It is believed that in this way the effect of greenhouse gases will be reduced. The society is oriented to the use of waste for the purpose of recycling. In order to use energy from biomass, energy producers must find a way to meet the needs of businesses, how to maintain economic efficiency, stable supply and adequate control of fuel. These processes include activity during the collection of biomass energy conversion and use of biomass residues. Parallel to this, there are attempts to solve the problem of the treatment and disposal of large quantities of sewage sludge. Some companies have developed technology that is excellent in sterilization of sludge, and also recycles sewage sludge as fuel and produces electricity and heat energy. The new system can meet the needs for effective treatment of sewage sludge, reducing greenhouse gas emissions and make use of sludge as a fuel in power plants and heating plants. This type of use of energy, gives hope that it is possible to use sewage sludge as fuel without carbon [1].

Thermal treatment of sewage sludge proved to be most effective when it comes to the impact on global warming, aquatic and terrestrial eco toxicity, acidification of land and agricultural products [2].

1. Thermal treatment of sewage sludge

The composition of sewage sludge is one of the most important factors in the proper method of choice for the treatment of sludge. For this reason, it is necessary to pay attention to the technical and an elementary analysis from which we get the energy value and composition of the sludge. The advantage of using sludge as fuel in cement kilns is often mentioned. The dry matter or lower heating value and composition of the sludge are important factors to be used as fuel. Up to the present, research in the Czech Republic showed that sediment consists of about 67% carbon, 5% hydrogen, 25% oxygen, 2.2% nitrogen, 0.8% sulfur. The dried sewage sludge has a similar composition as brown coal, or the calorific value of sludge is decreased (8-12 MJ / kg, compared with 21 MJ / kg for brown coal) [3].

In India, the research was conducted for sewage sludge, wood acacia, bagasse and rice husks. The research results are presented in Table 1.

Table 1. Technical and an elementary anliza different patterns of biomass and sludge [4].

Sample	Carbon (%)	Hydrogen (%)	Oxygen (%)	Ash (%)
Acacia wood	45,13	6,14	47,93	0,8
Bagasse	42,48	6,11	43,41	8,0
Rice husk	41,71	6,02	33,27	19,0
*Sewage sludge***	15,24	1,30	22,44	60,0
** Undigested, nitrogen = 1,02%				

Options for the utilization of energy obtained from sewage sludge are large. Depending on the organic compound in the sludge the possibility of utilization of energy can be divided into nine groups: [5]

1. Anaerobic digestion of sewage sludge,
2. Production of biofuels from sewage sludge,
3. Direct production of electricity from sewage sludge in microbial fuel cells,
4. Incineration of sewage sludge with energy recovery,

5. Co-incineration of sewage sludge in coal-fired power plants,
6. Gasification and pyrolysis of sewage sludge,
7. Use of sludge as an energy and raw material source in the production of Portland cement and building materials,
8. Supercritical wet oxidation of sewage sludge,
9. Hydrothermal treatment of sewage sludge.

2. Pyrolysis and gasification of sewage sludge

Pyrolysis and Gasification of sewage sludge is a thermal process in which the sludge (biomass) is heated at a temperature from 350-500 ^{0} C. Pyrolysis is a process in which the combustion process takes place without the presence of oxygen, while the gasification is using a controlled presence of oxygen. Gasification includes degradation of the dried sludge (biomass) at a temperature of typically about 1000 ^{0} C. Part of solid or gaseous products of pyrolysis is burned and used as thermal energy in the process of pyrolysis. Depending on the type of equipment and working conditions, there are a number of modified process. There are also techniques to combine the two processes. Figure 1 shows the scheme of the plant for the pyrolysis of sewage sludge.

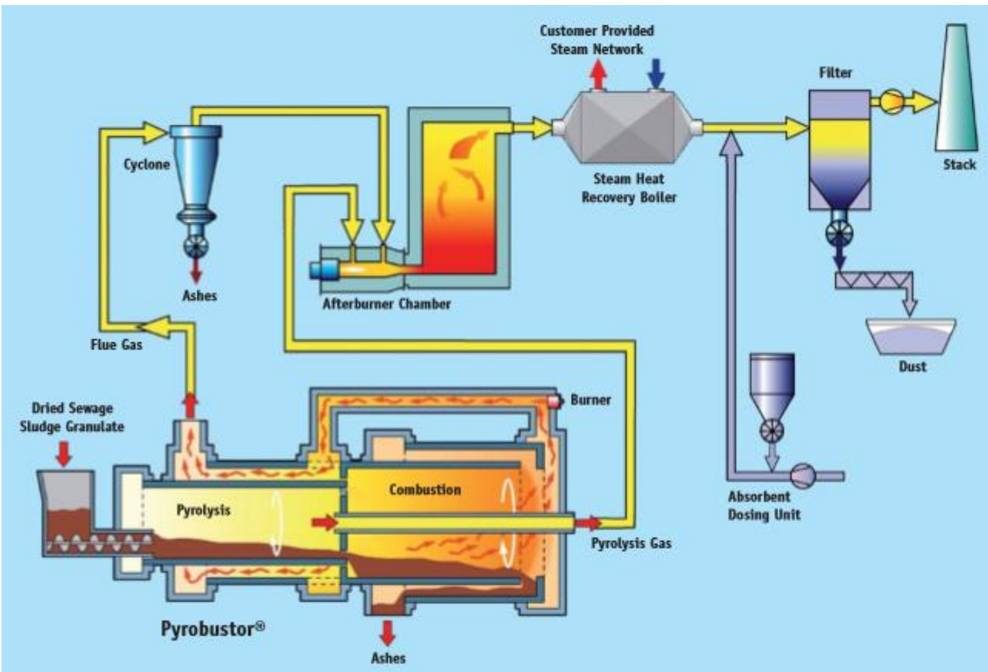

Figure 1. The process of pyrolysis of sewage sludge [6].

A lot of research is being implemented on pyrolysis and gasification of biomass. However, the research on pyrolysis and gasification of sewage sludge is very limited. Pyrolysis and gasification of sewage sludge have many advantages over classic combustion. One of the advantages is the combustion of flammable gases and conversion to electricity with high efficiency. Furthermore, gases may be used as basic chemicals or as fuel. However due to the presence of organic pollutants in sewage sludge, processing of gases can be complicated. Generally speaking, the process of pyrolysis and gasification is much more complex than combustion. There is another successful application of pyrolysis and gasification, which is applied in practice for the production of oil from sewage sludge, which can be used as fuel. Based on the existing data it cannot be said with certainty whet her pyrolysis and gasification will have an important role in solving the problem of sewage sludge.

2. Review of the treatment of sewage sludge in Europe

In Europe, production of sewage sludge per inhabitant is about 90 g / person per day and is derived from primary, secondary and tertiary wastewater treatment. Annual production in 1992 was about 5.5 million dry matter, this amount has increased to about 9 million tones until the end of 2005. This increase is a result of the practical implementation of the Directive on the treatment of urban waste water (91 / 271EEC), as well as the increased number of households connected to the sewage system and a larger share of tertiary treatment of waste water through which nutrients are being removed. In Germany, in 2002, 10 million tons of sludge has been produced, 30% of which is dry matter. This amount is approximately equal to 3.5 times the volume of the pyramid Giseh [7]. The number of population that is connected to the system for wastewater treatment in the area of Europe in percentage (%) is shown in Figure2.

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Belgium	51.4	53.2	*54.4*	*57.4*	68.7	71.0	72.8	75.0	77.0	82.0	84.0
Bulgaria	37.9	38.0	38.3	38.8	39.7	41.4	42.7	45.1	53.6	53.9	54.5
Czech Republic	70.6	70.8	72.8	71.9	73.0	75.4	75.7	76.9	78.0	78.0	79.8
Denmark	:	:	:	:	:	:	89.4	88.0	88.4	88.4	90.1
Germany	:	93.8	97.3	:	91.9	:	:	95.3	:	:	:
Estonia	70.0	71.0	73.0	73.0	73.5	79.5	79.5	78.3	81.1	81.2	82.1
Ireland	:	:	:	:	:	:	:	:	:	:	:
Greece	:	:	:	:	85.0	:	87.3	87.3	88.1	92.0	:
Spain	:	:	:	88.0	:	88.0	:	93.0	:	94.8	:
France	:	79.5	:	:	:	:	:	:	56.1	*56.1*	*55.4*
Croatia	:	:	:	:	:	:	:	:	27.0	:	:
Italy	:	:	93.6	:	:	:	83.0	:	:	:	:
Cyprus	22.9	28.4	29.8	:	:	:	:	:	:	:	:
Latvia	68.3	64.3	63.8	62.9	60.9	54.3	60.9	58.1	63.9	66.0	67.2
Lithuania	27.6	:	:	:	:	:	:	:	:	63.1	:
Luxembourg	88.1	:	:	:	:	:	:	91.3	90.9	96.1	96.3
Hungary	38.9	40.2	*41.7*	*45.3*	*49.8*	*50.0*	*52.1*	*69.5*	*71.1*	*72.8*	*72.6*
Malta	16.1	13.3	*13.2*	*9.3*	*8.4*	*14.8*	*15.2*	6.6	*93.2*	*93.1*	*92.9*
Netherlands	98.6	98.9	99.0	99.1	:	99.3	:	99.4	:	99.4	:
Austria	:	88.9	:	:	:	*92.6*	:	*93.9*	:	94.5	:
Poland	55.5	56.8	58.1	60.7	61.8	62.9	64.1	64.5	65.5	68.5	70.2
Portugal	32.0	:	42.6	37.0	51.0	52.0	55.8	:	:	:	:
Romania	:	*16.9*	16.9	:	:	:	:	22.0	31.0	32.7	35.5
Slovenia	19.9	29.3	32.1	47.6	48.8	51.1	52.9	52.5	54.0	54.2	54.9
Slovakia	:	:	:	:	:	:	:	:	:	:	:
Finland	:	:	:	:	:	:	:	83.0	*83.0*	*83.0*	*83.0*
Sweden	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	86.0	87.0	87.0
United Kingdom	:	:	:	:	:	96.9	97.0	99.5	:	:	:
Iceland	1.0	1.0	2.0	:	:	2.0	:	:	:	:	:
Norway	55.4	56.2	58.0	58.6	58.5	58.8	59.3	59.2	61.4	62.6	62.6
Switzerland	:	:	:	:	:	:	:	:	:	:	*98.0*
Albania	:	:	:	:	:	:	:	4.7	4.7	7.4	*22.0*
Serbia	5.4	5.8	6.4	6.9	6.9	7.5	8.9	8.6	8.9	9.0	9.4
Turkey	21.1	24.8	:	:	31.1	31.4	35.2	37.6	:	42.0	:
Bosnia and Herzegovina	1.5	1.5	1.5	1.6	1.6	1.7	1.7	1.7	1.8	1.8	1.8
Kosovo	:	:	:	:	:	:	:	:	0.6	0.6	0.6

Figure2. Share of the population connected to at least secondary urban wastewater treatment in percentage (%) [8]

The problem of the treatment of sewage sludge exists in most European countries. This problem is best to solved in Malta, where, with the construction of the plant for waste water treatment in 2011, coverage has reached 100%. Apart from Malta, the highest rate of treatment of sewage sludge has been reported in Belgium, Hungary, Poland, Bulgaria and Slovenia. In 2013, the highest percentage of treatment of sewage sludge was recorded in Malta (100%), the UK (99.5%), the Netherlands (99.4%), Luxembourg (98.2%), Spain (97.8%), and Germany (96.4%). In the previous table, the share of the population connected to the system for waste water treatment is shown. This part is increasing more than 80% for the 14 EU member states, for which data were available. Observed from the other side, less than 2% of households are connected to the system for the wastewater treatment plant in Romania, Croatia, Turkey, Albania, Serbia, Bosnia and Herzegovina and Kosovo. Although sewage sludge is produced per citizen, its composition depends on many factors. Sewage sludge contains many nutrients, but often contain high concentrations of harmful substances such as heavy metals, and many countries use different methods for its removal. In five EU countries: Portugal, Ireland, Italy, Luxembourg and Spain, at least three-quarters of sewage sludge is used as fertilizer in agriculture. On the other hand, about two-thirds of sewage sludge is composted in Lithuania and Finland. As an alternative form of disposal of sewage sludge and possibilities for expansion of pollution in agriculture, thermal form and disposal can be used. In the Netherlands, Belgium, Germany, Slovenia, Austria and Switzerland, the combustion is used as the main form of treatment, while the landfill as a form of treatment is practiced in Romania, Italy and Bosnia and Herzegovina [8]. Figure 3 shows the production and wastewater treatment in Bosnia and Herzegovina in the period of several years.

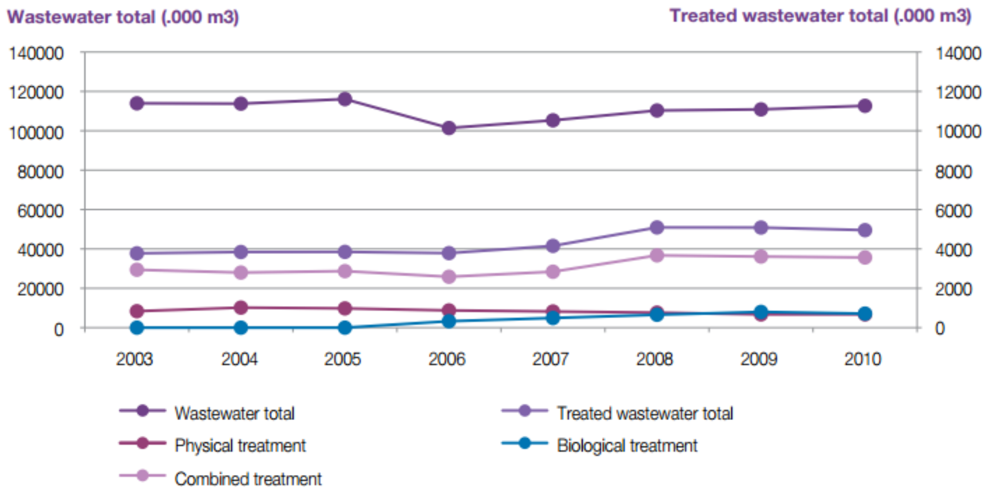

Figure 3. Wastewater treatment in Bosnia and Herzegovina

Since 2003 In Bosnia and Herzegovina, there was an a slight increase in user connection to the waste water treatment system. In the analyzed period (2003-2010) some progress has been achieved, if we take into account the ratio of the amount of water that is purified by a year to the total amount of waste water. In 2009, a positive upward trend in the quality of treatment has continued, as evidenced by the increase in the share of biological methods of treatment, while in 2010 there was a slight fall which can be seen in Figure 3.

In BiH, the problem of inadequate wastewater discharge is pronounced. Only a few municipalities in the Federation (Gradačac, Žepče, Odzak, Srebrenik and Trnovo in the Sava River basin; Ljubuski, Citluk, Grude and Neum in the Adriatic Sea basin) and two in the RS (Trebinje and Bileca in the Adriatic Sea basin) have operational facilities for treatment of sewage water [9].

Conclusion

The treatment of sewage sludge is currently a big problem. Since there are many ways for the treatment sewage sludge, it is important to choose the most effective. When effective treatment is mentioned, it is understood that the harmful substances are neutralized through treatment, the amount of the treated residue from the disposed sludge is reduced, the potential energy of the composition of the sludge is used and that the treatment has no effect of environmental pollution or said effect is very small. Most represented treatment of waste water is disposal or use as a fertilizer in agriculture. An important factor in defining the most suitable sludge treatment and final disposal may be a possibility of its re-use. It would be recommended to examine existing methods and to focus more on the possibilities for the thermal treatment of sewage sludge and sludge utilization as fuel to generate electricity and thermal energy. In the thermal treatment, the most effective treatment is a process of pyrolysis and gasification. In this case, the coefficient of utilization is the highest and the environmental impact is minimal. Using the technology of pyrolysis and gasification is much more complicated than conventional thermal treatment, and therefore, more attention should be paid to scientific research and the development of it. The motivation for this is great. Application of the concept of sustainable development, the reduction of greenhouse gas emissions and protecting the environment are just some of the things that can affect the application of sewage sludge treatment process of pyrolysis and gasification.

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