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# The limitations in co-combustion of municipal solid waste and sewage sludge in the grate type boilers

*Jan NADZIAKIEWICZ*[1]

[1] *Katedra Technologii i Urządzeń Zagospodarowania Odpadów, Politechnika Śląska, ul. Konarskiego 18, 44-100 Gliwice, e-mail. jan.nadziakiewicz@polsl.pl*

## Abstract

The European and Polish regulations are getting more restricted as to the amount of landfilled waste with biodegradovable fraction. The solution of this problem is agricultural or thermal utilization of this waste. Most popular and reliable thermal method of waste utilization is incineration in grate type boiler. But this technology has some restrictions regarding thermal parameters of the waste. In the paper the technological requirements according to the simultaineous municipal waste incineration with sewage sludge in the grate type boilers are discussed. The limitations come from the different moisture of waste and sludge as well as from the different heating values of both components of the fuel. The ratio of the sludge and the waste and the moisture content of the sludge after drying is presented in the Tanner drawing. Also the relation between the humidity of the sludge and its ratio in the mixture with the waste is shown.

**Keywords**: Waste incineration, sewage sludge, co-combustion, fuel characteristics.

## Streszczenie

Ograniczenia technologiczne równoległego spalania odpadów komunalnych i osadów na ruszcie

Przepisy Unii Europejskiej i Polski narzucają coraz większe ograniczenia na możliwości składowania odpadów zawierających frakcje biodegradowalne. Sposobem zmniejszenia ich ilości jest zagospodarowanie rolnicze lub termiczna utylizacja. Najpowszechniej stosowaną i najbardziej sprawdzoną technologią termicznej utylizacji jest spalanie na ruszcie, jednak i ta technologia ma pewne ograniczenia dotyczące parametrów spalanych odpadów. W referacie przedstawiono możliwości technologiczne i ograniczenia w równoległym spalaniu odpadów komunalnych i osadów ściekowych w kotłach rusztowych. Ograniczenia wynikają z różnych wilgotności i różnych wartości opałowych składników paliwa a także z ograniczonej możliwości odbioru ciepła w komorze spalania i przepustowości rusztu. Pokazano przykładowe wartości parametrów odpadów i osadów oraz parametry paliwa z nich wytworzonego.

**Słowa kluczowe**: spalanie odpadów, osady ściekowe, współspalanie, charakterystyka paliw

## 1. Introduction

Constantly growing volume of waste and sewage sludge generated in the municipal agglomerations creates great ecological an sanitary problems. The main reason is large load of organic fractions and its biological decay with pollutant emission both in gas and liquid form. The other feature is the free land occupation by the landfill installations. The European and Polish regulations try to reduce this hazard and some restrictions and limitations are put on the amount of organic fraction in the landfill waste.

To reduce this hazard two methods are available: agricultural use of waste and sewage sludge or their thermal utilization. The first of the two is good from the ecological point of view but it is limited by the pollutant substances in the waste (mainly heavy metals) that can pollute the agricultural products and the available area for its application. From the other side thermal methods are final solutions of the problem but they influence the environment in other way. The main advantage of thermal methods is their universality and possibility of utilization of various types of waste and sludge of various parameters. The important parameter of waste is the water content in the sludge and its low calorific value. The limiting thermal requirement for the waste to be thermally treated is its minimal calorific value ensuring the autothermal (self-sufficient) incineration determined by the applied method.

In the paper the possibilities of co-combustion of the municipal solid waste with sewage sludge were discussed and the technological limitations for the grate type incinerator are shown.

By the year 2013 the EU and Polish regulations [6] require reduction of the biodegradable fraction of the waste to be landfilled, namely:

- It is not allowed landfilling of mixed waste (20 01 01) and the fraction sorted of the size <20mm and >80mm ( waste code 19 12 12) without mineralization (level of TOC < 5% dry matter, ignitron loss < 8% d.m., heat of combustion < 6 MJ/kg d.m.) – this is not possible to achieve in practice without thermal treatment of the waste.
- It is required that all volume of the waste is utilized.
- As preferable method of utilization the incineration of the fuel prepared from waste is suggested as well as material recycling and organic matter recycling.
- The amount of biodegradable fraction of waste must be reduced to 75% in 2010, 50% in 2013 and up to 35% in 2020 of the amount landfilled in 1995. This is shown In Fig.1.1.

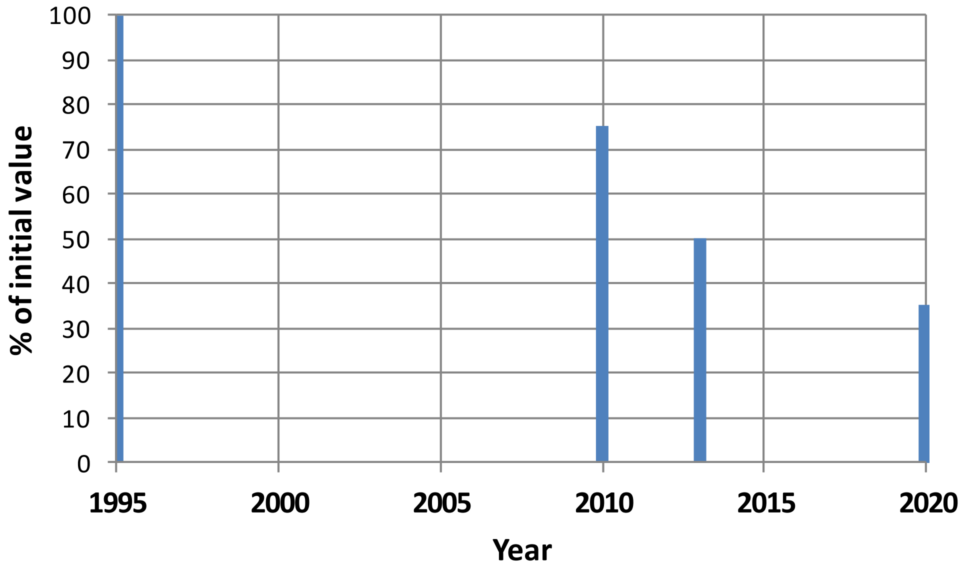



Fig. 1.1. The amount of biodegradowable fraction of waste allowed for landfilling %.

## 2. Technology of thermal waste utilization.

Several methods of thermal waste utilization are in practical use and are reliable enough to be commercially profitable. In practice two are in common use: waste incineration and waste gasification. Incineration is the universal method and can be applied to various types of waste, it is flexible and low sensitive to the change of waste parameters. The incineration process can be realized in several types of installations [1]:

- Grate type of furnace with various types of grates.
- Rotating drum type furnace.
- Fluidized bed type furnace.

In the most of operating installations the grate type method is applied. Its advantage is large hour capacity, low requirements regarding the quality and uniformity of the waste and low vulnerability of the grate. The rotating drum technology is applicable to lower capacity of waste and for waste of medium calorific values. Fluidized bed technology requires stable quality of waste as regards size fractions, density and humidity.

The flexibility of grate type furnace operation makes possible incineration of various types of waste as well as their mixtures of various compositions. One of these possibilities is co-combustion of municipal solid waste (MSW) with the sewage sludge. The large difference between parameters of these two components (mainly in water content and calorific value) needs careful choosing of proportions of the two components of the fuel supplied to the grate.

## 3. Parameters of the fuel for grate incineration

Both municipal solid waste and sewage sludge are generated in the same agglomerations

this makes sensible their parallel utilization in one incineration installation. This is reasonable mainly in not very big municipalities, where investing in separate installations for MSW and sludge is not economically justified. The incineration in one furnace uses part of the heat gained from relatively high calorific MSW to dry and incinerate low calorific sludge. This idea of combined investment for both types of waste is now often analysed as possible choice.

The technology chosen for parallel incineration of MSW and sludge must take for analysis the fact that the sludge from the sewage treatment plant still have about 80% of water and its calorific value is in the range of 1 to 4 MJ/kg wet [2]. That small value does not support energetic self-sufficiency of the process. The one possibility to incinerate the sludge is to utilize the heat of municipal solid waste of a calorific value 8 to 10 MJ/kg by mixing it with the sludge. Such composed fuel can be burned in the industrial grate boiler. The needed calorific value of the fuel can be obtained by mixing the appropriate amount of the sludge with MSW and it depends on the calorific values of both components and their water contents.

The second parameter that must be taken by planning the new installation is the maximal fuel rate of the grate type furnace and maximal thermal power of the boiler. These parameters must be taken for evaluation with some margin to cope with the variations of the quality and amounts of the waste to be burned.

### 3.1. The dependence of calorific value of the mixed fuel on water content of the sludge and sludge-waste ratio.

In technological practice the minimal calorific value of fuel suitable for grate type boiler is assumed as 6 MJ/kg. The experience gained in many commercial installations show that this value secure the self-sufficiency of the process. If the fuel is composed of the MSW and sewage sludge the final parameters depend on their ratio and water contents of both components. This relation can be shown in the diagram (Fig.3.1.):

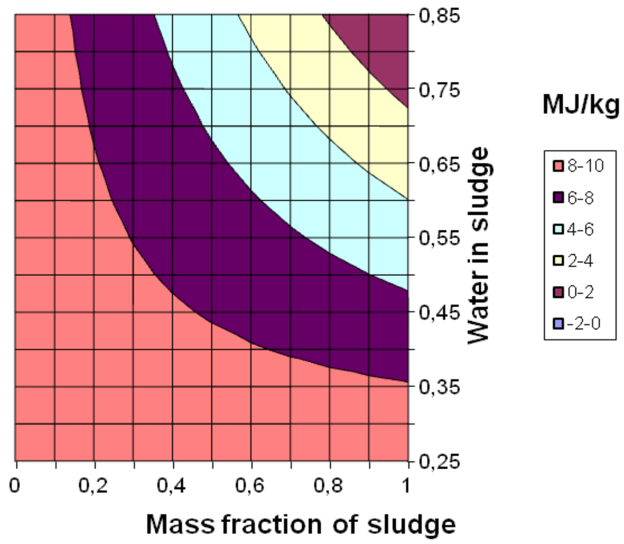



Fig.3.1. The relation of mixed fuel calorific value on the sewage sludge to MSW ratio and on the water contents in the sludge.

As can be seen from the diagram, the critical calorific value 6 MJ/kg can be obtained by mixing various amount of the sludge of different dampness with municipal solid waste.

### 3.2. The numerical example of mixed fuel parameters.

The thermal parameters of fuel prepared from the municipal solid fuel and sewage sludge can be calculated according to the mass and energy balance equations. These parameters depend mainly on the sludge-waste ratio and on the sludge moisture. As a real example for a given municipality following amounts and parameters of both components were assumed:

*Municipal solid waste MSW*

It was assumed that the MSW, after segregation of non-combustible fractions have following parameters (Table 3.1.):

Table 3.1. Average composition of MSW taken for analysis.

| No. | Parameter | Unit | Average value |
|---|---|---|---|
| 1 | Amount | Mg/year | **100 000** |
| 2 | Moisture content | % mass | **23** |
| 3 | Dry mass content | % mass | **77** |
| 4 | Organic substance | % mass | **41** |
| 5 | Mineral substance | % mass | **36** |
| 7 | Lower calorific value | MJ/kg | **9,3** |

The MSW of these parameters will be mixed i various proportions with the sludge of following parameters:

*Sewage sludge to be incinerated*

The average parameters of the sludge generated in some installations are given in Table 3.2.:

Table 3.2. Average composition of the sludge taken for analysis.

| No. | Parameter | Unit | Average value |
|---|---|---|---|
| 1 | Amount | Mg/year | **50 000** |
| 2 | Moisture content | % mass | **80** |
| 3 | Dry mass content | % mass | **20** |
| 4 | Organic substance | % mass dry | **63,5** |
| 5 | Mineral substance | % mass dry | **36,5** |
| 6 | Heat of combustion Qi | MJ/kg wet | **14,23** |
| 7 | Lower Calorific Value | MJ/kg wet | **1,0** |
| 8 | Sulphur combustible | % mass dry | **0,35** |
| 9 | Chlorium | % mass dry | **0,15** |

It was assumed, that for preparing the fuel to be incinerated the mixture of 1/3 of sludge (of moisture 80 % and dryed out to 30%) and 2/3 of MSW of given in Tables 1. and 2. Parameters will be prepared.

*Fuel for incineration*

As a result of mixing MSW with the sludge of given amounts and parameters the fuel of following parameters will be produced for incineration (Table 3.3.):

Table 3.3. Parameters of mixed fuel for incineration

| No. | Parameter | Unit | MSW | Sludge (30% moist) | Mixed fuel |
|---|---|---|---|---|---|
| 1 | Amount | Mg/year | **100 000** | **14 286** | **114 286** |
| 2 | Moisture content | % mass | **23** | **30** | **23,9** |
| 3 | Dry mass content | % mass | **77** | **70** | **76,1** |
| 4 | Lower Calorific Value | MJ/kg wet | **9,3** | **8,9** | **9,2** |

The comparison of Lower Heating Values (LHV) of MSW and sludge taken to analysis is shown in Fig.3.2. The line representing 6 MJ/kg assumed as “safe” is also shown. This value of LHV can be obtained by mixing both components in various proportions.

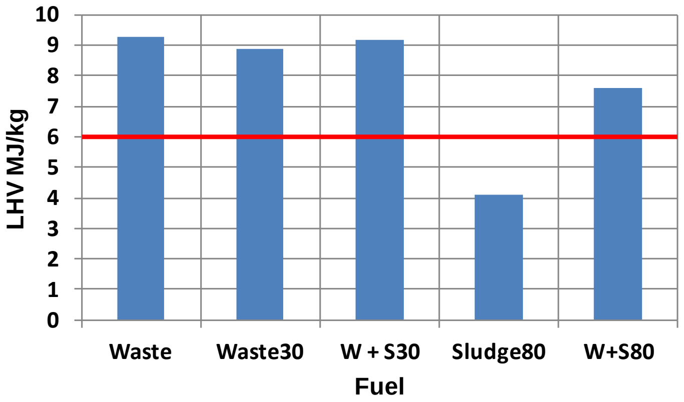



Fig.3.2. Comparison of Lower Heating Values of MSW and fuels composed with sludge. Description: W+S30 = MSW + sludge 30%. W+S80 = MSW + sludge 80%.

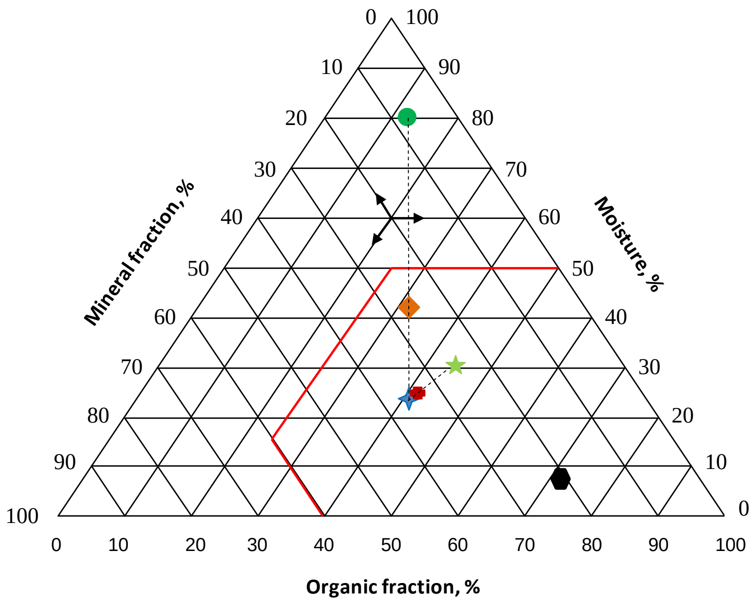
## 3.3. Graphical representation of parameters of the fuel

The main thermal parameters of the fuel can be presented in a three-axes diagram called Tanner diagram. The three axes represent organic fraction %, water content % and mineral content % of the fuel. Each point on the diagram represents the sum of these three parameters equal to 100 %. The experience of many installations show the field representing parameters sufficient for incineration in a typical installation. They can be roughly defined as [1]:

- Moisture content < 50%
- Mineral content (non-combustible) < 60%
- Organic content (combustible) > 25%

The parameters of the MSW, sludge and fuel composed out of these two components given in Table 3 can be shown as points lying on the joining lines as shown in Fig.3.3.

As additional points the sludge of moisture 80% (just after mechanical dewatering), sludge pre-dried to 30 % of moisture and points representing the fuels composed out of these types of sludge mixed with MSW are also shown on this diagram. As a reference the point representing the parameters of hard coal is also shown in this diagram.




| Mixed fuel | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **MSW** | **Sludge 30%** | **MSW + sludge30** | **Sludge 80%** | **MSW + sludge80** | **Hard coal** | **Unit** |
| **Amount** | 100 000 | 14 286 | 114 286 | 50 000 | 150 000 | | Mg/rok |
| **Moisture** | 23 | 30 | 23,9 | 80 | 41,8 | 7,0 | % w. |
| **Dry fraction** | 77 | 70 | 76,1 | 20 | 58,2 | 93,0 | % w |
| **Mineral fraction** | 35,7 | 25,6 | 34,4 | 7,5 | 26,3 | 20,0 | %w |
| **Organic fraction** | 41,3 | 44,4 | 41,7 | 13,1 | 31,9 | 73,0 | %w |
| **LHV** | 9,3 | 8,91 | 9,2 | 4,1 | 7,6 | 22,0 | MJ/kg w |

Fig.3.3. Thermal characteristics of MSW, sludge and fuel.

## 4. Technological limits for incineration in a grate type furnace

### 4.1. Heat for drying the sludge

As was mentioned before the sludge can be pre-dried to improve its calorific parameters. This process need some amount of heat to evaporate water from 80 % to 30 % of water content. To ensure self-sufficiency of the process part of the heat of incineration of the mixed fuel can be used for this purpose. The most reliable system is separate drying device and special incineration furnace for the fuel prepared from the MSW and sludge, but from the other side, this system is not energy effective and needs additional investment costs [3].

In every case study one must analyse the energy balance of each element of the system and the balance of the whole system. For the dryer – furnace configuration the example energy balance is shown in Fig. 4.1.

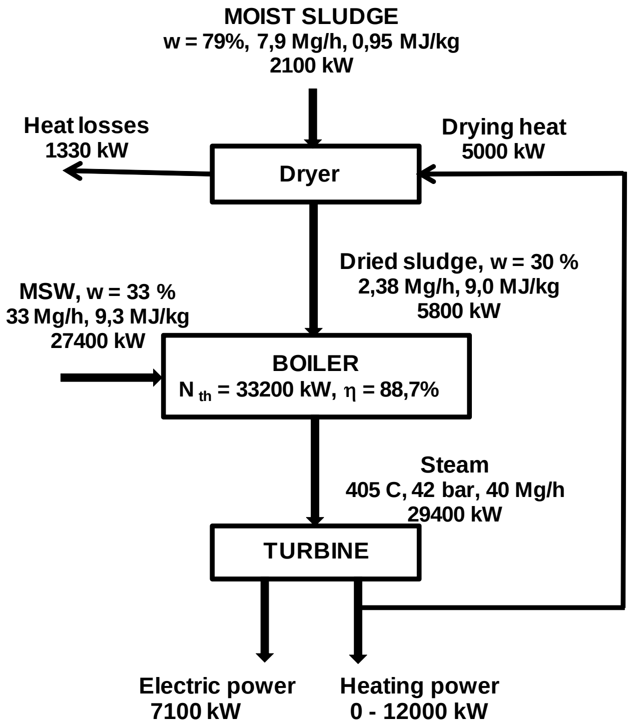



Fig. 4.1. Scheme of energy balance in the MSW + sludge incineration installation.

As can be seen from this diagram the heat of evaporation of moisture from the sludge takes about 15 % of the total heat gained in the boiler, but it is partially compensated by increase of heating value of the sludge.

## 4.2. Technological limitations of boiler and grate capacity.

Most often used technology of waste utilization is a grate-type boiler. This technology is reliable and variations in fuel properties have not great influence on the process. The construction of the grate depends to a great extend on the properties of the fuel like its segregation, size of particles, moisture etc. The special attention is paid to the way the fuel is loaded on the grate at the entrance of the furnace and the maximal thermal power of the boiler. For the medium size boiler (about 30 MWth) the most convenient is a travelling grate type with spreader type of fuel feeding. This system is not technically complicated, is reliable and long lasting and it is relatively cheap

The characteristics of the grate type boiler furnace can be described as a relation of thermal power generated by the boiler and fuel stream of a given parameters [4]. Two types of limits must be taken into account in this type of furnace:

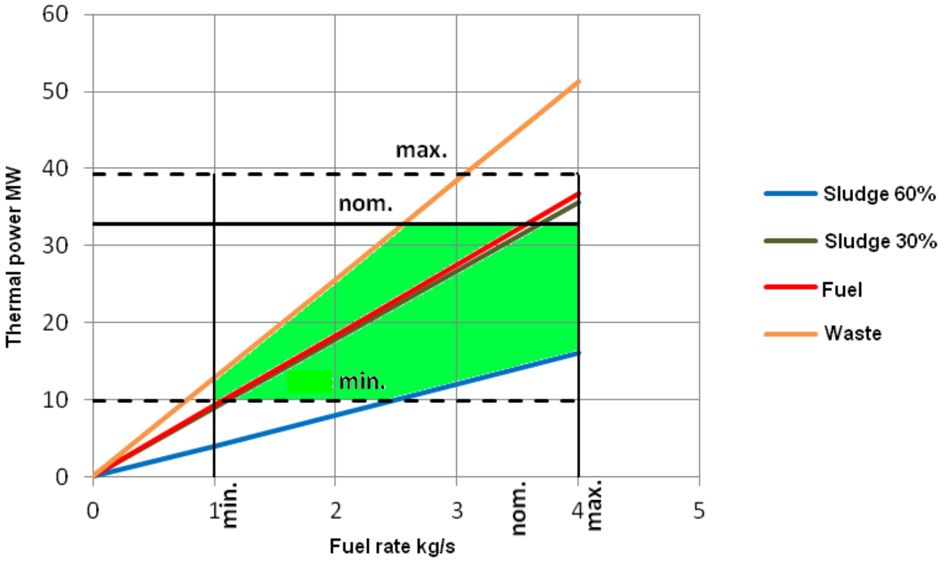
- Maximal thermal power generated on the grate and received by the boiler part without the risk of overheating the elements of the grate and the boiler,
- Maximal volumetric capacity of the grate system.

For a given waste and sludge parameters one can construct the diagram showing the parameters field restricted by these two limits. As an example following parameters were assumed for the furnace:

- Fuel rate (Capacity of the grate - nominal) 3,56 kg/s
- Lower Heating Value of the fuel 9,2 MJ/kg
- Thermal power (nominal) 32,7 $MW_{ther}$
- Maximal thermal power 120 % nominal
- Minimal thermal power 30 % nominal

- Range of LHV variations from 4 MJ/kg (sludge 60% moist.) to 12,8 MJ/kg (dry sludge).

The boiler characteristics has the form shown In Fig. 4.2.




Rys. 4.2. Boiler characteristics fed with the fuel from waste.

The figure show that nominal capacity of the grate is reached for nominal feeding ratio. The increase of the fuel rate or its calorific value can result in excess in the thermal power of the boiler exceeding maximal temperature of the grate and flue gas. This increase of calorific value can be the effect of reduced amount of the sludge in the fuel or by the lower moisture content in the sludge. On the opposite the reduction of calorific value or amount of the fuel can result in reduction of the temperature and finally flame-out of the boiler. This is because the amount of fuel fed to the grate is limited by the maximal thermal output of the boiler.

The limit of the fuel rate can be also reached with the grate linear velocity and the fuel layer thickness on the moving grate. This effect needs special attention with fuel from waste because of its low bulk density on the grate much lower than that of classical fuels. To illustrate this effect the values on the horizontal axis should be expressed in $m^3/s$ instead of kg/s. The maximal fuel rate transported on the grate should be defined experimentally in real conditions and taking into account the velocity of the air flowing up the grate and floating fuel particles.

## 5. Conclusions

The waste incineration in various installations is a promising technology both from ecological and economical points of view. Nevertheless some problems occur when various types of waste should be utilized with different properties like moisture content, calorific value etc. Incineration process becomes even more complicated when two types of waste are to be incinerated in one installation. In this case some minimal thermal parameters and continuous fuel flow on the moving grate must be provided to ensure proper process parameters. The simplest solution for small communalities generating municipal solid waste and sewage sludge is co-combustion both types of waste in one installation. The best solution in this case seems to be a moving grate boiler fed with mixed fuel prepared of the two types of waste. The proportions of MSW and sludge depend on their parameters and possibilities of pre-drying of the sludge to increase its calorific value. Special attention should be paid to avoid the effect of sticky phase of the sludge depending on its temperature range, when operating and mixing the sludge with other fuels is difficult.

The other question to be solved is the type and capacity of the boiler to ensure the utilization of all predicted amount of waste and the sludge taking into account changes in their volume and parameters during the time of operation. This needs knowing the characteristics of the boiler to avoid the risk of overloading the system (overheating) and to be sure the flame in the furnace will never be extinguished.

It seems that the most reliable and flexible system for not very big amounts of the waste is the moving grate system with separate waste and sludge feeding lines, easy to regulate the ratio of both components.

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