SLOVENSKI STANDARD
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Karakterizacija blata - Dobra praksa za seģiganje blat z maģļ obami in ostanki ter brez njih

Characterization of sludges - Good practice for sludges incineration with and without grease and screenings

Charakterisierung von Schlämmen - Anleitung für die gute fachliche Praxis bei der Verbrennung von Schlamm mit und ohne Fett und Rechengut

Caractérisation des boues - Bonne pratique d'incinération des boues avec ou sans graisse et refus de dégrillage

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This CEN Report was approved by CEN on 16 June 2001. It has been drawn up by the Technical Committee CEN/TC 308.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This document has been prepared by CEN /TC 308, "Characterization of sludges".

This document is currently submitted to the CEN BT.

The status of this document as CEN Report has been chosen because the most of its content is not completely in line with practice and regulation in each member state. This document gives recommendations for a good practice but existing national regulations concerning the sludges incineration remain in force.

Introduction

The purpose of this CEN Report is to describe good practice of the sludge incineration in order to ensure a safe and economical operation. The main goals are to :

- describe the principal design parameters relevant to different process schemes ;
- assess the operating procedures able to perform optimal energy consumption, emissions control and equipment durability ;
- provide the responsible authorities with well established and easily applicable protocols for control purposes ;
- promote the diffusion of this practice and favouring the formation of a public opinion consensus ;

potential advantages of high temperature processes include :

- reduction of volume and mass of sludge ;
- destruction of toxic organic compounds, if present ;
- energy recovery.

Anyway, priority should be given to reduction of pollutants at the origin and to recover ,

if technically and economically feasible, valuable substances (phosphorous and potassium) in sludge and derived products.

The following abbreviated terms necessary for the understanding of this report apply :

COD Chemical oxygen demand

LOI Loss On Ignition

MHF Multiple Hearth Furnace

FBF Fluidised Bed Furnace

RKF Rotary Kiln Furnace

EF Electric Furnace

CF Cyclone Furnace

PCDF Polychlorodibenzofurans

PCDD Polychlorodibenzodioxins

PCB Polychlorinated biphenyls

PAH Polycyclic aromatic hydrocarbons

GCV Greater Calorific Value

LCV Lower Calorific Value

VOC Volatile organic carbon

1 Scope

This CEN Report describes good practice for the incineration of sludges with and without grease and screenings.

This CEN Report is applicable for sludges described in the scope of CEN/TC 308 specifically derived from :

— night soil ;

— urban wastewater collecting systems ;

— urban wastewater treatment plants ;

— treating industrial wastewater similar to urban wastewater (as defined in Directive 91/271/EC) ;

but excluding hazardous sludges from industry.

This European standard is not applicable to co-incineration of sludge and other wastes, (either urban or hazardous) (see CR 13768) and to the use of sludge in cement kilns.

Annex A gives tables of data for different typical parameters for sludge, furnace, ash, etc..

2 References

EN 1085, *Wastewater treatment – Vocabulary*.

EN 12832, *Characterization of sludges – Utilisation and disposal of sludges – Vocabulary*.

EN 12255-8, *Wastewater treatments plants – Part 8 : Sludge treatment and storage.*

CR 13768, *Characterization of sludges – Good practice for combined incneration of sludge and household wastes.*

prEN 13965-1, *Characterization of waste – Terminology – Part 1 : Material related terms and d*EF*initions*.

prEN 13965-2, *Characterization of waste – Terminology – Part 2 : Management related terms and d*EF*initions.*

3 Terms and definitions

For the purposes of this CEN Report, the following terms and definitions which apply are those given in :

— Directive 91/271/EC (Concerning urban waste water treatment) ;

— Directive 75/442/EEC (The Waste Framework Directive) as amended by EU Directive 91/156/EEC ;

— Directive 89/369/EEC (Concerning prevention of atmospheric pollution derived from urban solid waste incineration plants) ;

— EN 1085, EN 12832, and prEN 13965-1 and 2.

4 Sludge properties

Sludge characterisation for the assessment of combustion processes involves the evaluation of chemical and physical parameters and specific properties.

4.1 Chemical characteristics

The main chemical characteristics to be taken into account are :

— organic and inorganic chlorine ;

— sulfur ;

— phosphorus and nitrogen ;

— other halogens ;

— organic micropollutants with main regard to chlorinated hydrocarbons, phenols and polyphenols, polychlorinated biphenyls (PCB), pesticides and polycyclic aromatic hydrocarbons (PAH) ;

— elemental analysis of loss on ignition (*LOI*) ;

— trace elements.

The toxicity of emissions (gaseous, liquid, solid) from incineration generally depends on the presence of above chemicals at origin, when improper operating conditions occur.

a) Sulfur

The sulfur content of sewage sludge ranges generally from 0,5 % to 2 % by dry mass. Because a fraction of the sulfur is present in the oxidised sulfate form, not all of this sulfur is converted to sulfur dioxide during combustion. Sulfur dioxide then combines with moisture, either in the waste gas treatment system or in the atmosphere, to form sulfuric and sulfurous acids.

b) Phosphorus and nitrogen

Phosphorus can be present in sewage sludge in concentration ranging from 1 % to 5 % by dry mass. This concentration mainly depends on the phosphorus load in the wastewater system and on the level of phosphorus removal accomplished in the treatment plant. Nowadays in some countries the phosphorus concentration in urban wastewater is decreasing due to substitution of phosphorus in detergents with other products. During combustion phosphorus and phosphorus compounds are converted to calcium phosphate which can be present in the furnace ash up to 15 % mass fraction of P_2O_5 in certain conditions, leaching of phosphorus from ashes should be taken into account.

Nitrogen content of sewage sludge (2 % to 12 % dry mass) can be converted during combustion to molecular nitrogen or to NO_x, depending on the temperature and atmosphere inside the furnace. NO_x formation from fuel bound nitrogen can be controlled by restricting the air flow to the minimum excess above the stoichiometric requirement and by staging the air flow to the furnace (see 8.1).

c) Chlorine and other halogens [1)]

Organic and inorganic chlorine compounds play an important role in the combustion processes for the tendency of the chlorine radicals to bind to active radicals, like O*, H* and OH*. This determines a decrease in the combustion rate with the possibility of toxic compounds formation. Chlorine and other halogens are also responsible for the presence in the exhaust gases of acidic compounds which are undesirable for corrosion problems involved, especially at high temperatures. The presence of organic chlorine in sewage sludge is generally negligible (less than 50 mg/kg dry mass) but the concentration of inorganic chlorine can be some units per cent dry mass depending on chlorine presence in the sludge water fraction and on the use of inorganic conditioners. The industrial sludges similar to sewage sludge mentioned in Directive 91/271/EC, which derive from food and/or

1) Bromine can exert similar effects than chlorine but the organic compounds are easier formed and they can also be easier destroyed at high temperatures.

beverage transformation and production, do not contain organic chlorine. As for swage sludge, inorganic chlorine can be present in such sludges if $FeCl_3$ is used as conditioner.

d) Organic micropollutants

Although the presence of organic micropollutants in sewage sludge can be in some cases noticeable, they generally do not pose problems in incineration. Chemical analysis should can include, for particular cases of contaminated sludges, the compounds which are recognised to be recalcitrant to a thermal degradation.

e) Elemental analysis

Elemental analysis of loss on ignition (C, H, N, S, O) is important to predict flow rate and composition of flue gas and therefore to design the purification gas line. Typical elemental analysis of primary, secondary, mixed and digested sludge is given in Table A.1.

f) Trace elements

Trace element presence in sewage sludge has to be considered for their potential tendency to be transferred in the gaseous phase (especially for mercury). They (except mercury) can be concentrated in fly ashes collected in bag and electrofilters (arsenic, lead, cadmium and zinc). Mercury generally escapes with flue gases but can be condensed in scrubbers or captured by activated carbon filters.

Trace elements are generally present in sewage sludge in very variable concentrations depending on the presence of industrial effluents in the wastewater. Table A.2 gives an indication of the most common range of variation and the typical values of trace element concentrations, but it has to be pointed out that, currently, the trace element presence in sewage sludge is decreasing due to a more effective control of undesirable pollutants input to the sewerage system.

4.2 Physical-chemical characteristics

The main physical-chemical characteristics to be taken into account are :

- dry matter ;
- physical consistency ;
- loss on ignition (*LOI*) ;
- calorific value ;
- presence of grease, scum and screenings.

Rheological properties also play an important role, especially as far as the design of feeding system is concerned.

a) Dry matter

In incineration of sewage sludge dry matter is a variable affecting both fuel requirement and exhaust gas production. Generally any increase in dry matter is believed to be beneficial in the combustion for the reduction in fuel requirement. Until the condition for autogenous combustion is reached the increase in dry matter corresponds also to a decrease in combustion gases production. It should be pointed out that any further increase of dry matter beyond the limit of autogenous combustion could be not very convenient because this entails a more abundant gas production, especially if dilution air is used instead of water for the control of the combustion chamber temperature. The use of water, on the contrary, reduces the quantity of recoverable heat in the boiler.

Moreover, if after burning of combustion gases should be accomplished, the feeding of too dry a sludge to the furnace implies also very abundant fuel requirements in the after burning chamber due to high gas production.

Therefore, thermal drying of sludge before incineration has to be properly designed and operated in order to attain an optimal drying level. Dried and dewatered sludges can be mixed, if necessary, to avoid too high not needed dry matter concentrations.

b) Physical consistency

Physical consistency of sludge should be adapted to furnace and its feeding system.

Depending on the dewatering device a crumbly product could be needed before feeding the incineration furnace.

c) Loss on ignition and calorific value

Calorific value of sludge is probably the most important parameter for the evaluation of combustion processes. It represents the heat quantity developed in the combustion by the unit mass of material in standard conditions.

As a first approximation the Greater Calorific Value (*GCV*) can be evaluated by the Du Long equation, if the elemental analysis of combustible material is known :

$$GCV = 32\,810\ C + 142\,246\ (H - O/8) + 9\,273\ S \quad (1)$$

where

GCV is in kJ/kg *LOI* ; and

C, H, O and S are the mass fraction of the elements in the loss of ignition.

The above formula gives an overestimation of the heat value of sludges with high organic nitrogen content because : a) the nitrogen will be associated with the hydrogen as an amine, b) the production of nitrogen oxide in the amine combustion reduces the hydrogen heat release.

The following equation can be used to take into account the above effects :

$$GCV = 32\,810\ C + 142\,246\ (H - O/8) + 9\,273\ S - [2\,189\ N\ (1 - \mu) + 6\,4894 N\ \mu] \quad (2)$$

where

μ represents conversion (mass fraction) of nitrogen to nitrogen oxide, generally in the range 2 % to 7 %.

Lower calorific value (*LCV*) can be also evaluated (Nielsen and Simonsen, 1994) by measuring the chemical oxygen demand *COD* and the total Kjeldahl nitrogen (*TKN*) (ammoniacal + organic nitrogen) and using the formula :

$$LCV = 13\,700\ COD + 19\,000\ TKN \quad (3)$$

where

LCV is in kJ/kg *LOI* ; and

COD and *TKN* are expressed in kg/kg *LOI*.

COD of sludge generally varies in the range of 1,5 kg to 1,8 kg O_2/kg *LOI* and *TKN* in the range 0,02 kg/kg *LOI* to 0,09 g/kg *LOI*.

Typical calorific values of municipal wastewater sludges range from 22 100 kJ/kg *LOI* to 24 400 kJ/kg *LOI* (anaerobically digested primary) to 23 300 to 27 900 (raw primary). Secondary sludges display values between 20 700 kJ/kg *LOI* and 24 400 kJ/kg *LOI*.

The variability of the calorific value mainly depends on the elemental analysis of sludges : when the hydrogen content is higher also the calorific value displays higher values as for primary sludge in comparison with secondary and with digested sludge.

LCV can be estimated considering the water present in the sludge (1 – *X*), being *X* the fraction of dry solids, and the combustion water (9 H *LOI*) :

$$LCV \text{ (kJ/kg sludge)} = GCV\ X\ LOI - 2\,440\ (9\ H\ LOI + 1 - X) \quad (4)$$

where

LOI is the loss on ignition with respect to dry solids (kg/kg).

If the lower calorific value of loss on ignition is known (LCV_{LOI}) the lower calorific value of wet sludge can be easily evaluated by :

$$LCV = LCV_{LOI}\ X\ LOI - 2\,440\ (1 - X) \quad (5)$$

As a first approximation for LCV_{LOI} a value of 23 000 kJ/kg *LOI* can be assumed.

d) Presence of grease, scum and screenings

Grease, scum and screenings can be incinerated together with sludges but generally they pose several problems.

Screenings clog feed mechanisms for certain types of furnace and therefore a grinding or shredding process is advisable before feeding.

Screenings also contain bulky and non-combustible materials, which create problems in the ash disposal system.

Skimming generally contains more than 95 % moisture and therefore they should be thickened to at least 25 % solids before incineration. Skimming is difficult to handle in the thickened state due to their viscosity and a heating process to 70 °C to 80 °C is generally requested to get skimming pumpable. This scum solids should be ground to a size not exceeding 6 mm. *GCV* of skimming and screenings are in the range 37 000 kJ/kg to 44 000 kJ/kg dry solids and 23 000 kJ/kg to 25 600 kJ/kg dry solids, respectively.

Quantities of screenings are strictly dependent on the screen opening : they can vary in the range of $3x10^{-6}$ m^3/m^3 to $40x10^{-6}$ m^3/m^3 of sewage for opening of 12 mm to 25 mm (the upper limits apply to the reduced openings). As dewatered sludge production can be approximately evaluated in 1 l/m^3 of sewage the screenings production can be accounted in approximately 0,2 % to 4 % in mass of sludge production, considering that the density of wet screenings is 640 kg/m^3 to 1 000 kg/m^3.

Quantities of scum are very much dependent on the quality of the sewage and on the collecting system in the wastewater treatment plant : the highest values can be as high as 17 g of dry solids by cubic meter of sewage which means up to 1,7 % of sludge production. At a concentration of 25 % this value increases to 6,8 %.

Addition of scum and grease can result in operating and safety problems : due to their high energy content an increased volume of exhaust gases are suddenly produced in the heating space. It could happen that suction blowers, responsible for vacuum production in the furnace are not able to draw off the developed explosive gas immediately, which, therefore, can escape in the ambient air.

An operator has to take measures against such a situation and has to control appropriately any addition of combustible material different from sewage sludge.

5 Combustion fundamentals

Combustion is an oxidation reaction carried out at high temperature: the union of oxygen with carbon, hydrogen and sulfur yields energy and products of combustion, namely, carbon dioxide (CO_2), water (H_2O) and sulfur dioxide (SO_2). Organic nitrogen is preferentially converted to nitrogen gas but a certain amount (2 % to 7 %) can also be further oxidised to nitrogen oxide (NO).

The nitrogen in the air is also candidate to be converted to oxides of nitrogen (NO_x). This phenomenon begins to be noticeable at temperatures higher than 1 100 °C and increases with any further increase of temperature.

The maximum temperature achieved by the combustion of a fuel will result from the balance between the energy produced and/or the energy input and that of combustion products. The heat released by the combustion of a substance is then used to increase the temperature of the combustion products to the equilibrium temperature. The amount of heat required to raise a unit weight of gas, liquid, or solid of one degree is the specific heat of the material. In Tables A.3 and A.4, the main properties of gaseous products of combustion are shown.

All oxidising combustion reactions require some excess air to ensure that the reaction proceeds rapidly to completion. The amount of excess air required is a function of time of stay, temperature and turbulence, commonly referred to as the "3Ts of combustion". Generally as turbulence is maximised, excess air can be decreased. Turbulence provides more opportunities of contact between fuel and oxygen and changes substantially for various types of combustion units. High efficiency burners may employ as low as 20 % to 30 % excess air while less efficient furnaces, like multiple hearth and rotary kiln furnaces, need 100 % to 125 % excess air at least. As excess air quenches the combustion temperature it is desirable to minimise the quantity to be employed especially when auxiliary fuel is needed to sustain combustion. This effect can be reduced by air pre-heating. If insufficient excess air is added to the furnace or if one or more of the "3Ts" concepts are lacking, the combustion operation will generate smoke and products of incomplete combustion, thus making incineration operation not acceptable.

6 Equipment characteristics

6.1 Incineration systems

The type of incinerator most commonly in use for sludge incineration is the Fluidised Bed Furnace (FBF). Other types are : Multiple Hearth Furnace (MHF), Rotary Kiln Furnace (RKF), combination of MHF and FBF, Electric Furnace (EF) and Cyclone Furnace (CF).

They can be combinated with a dryer.

*a) Fluidised Bed Furnace (*FBF*)*

It is a cylindrical refractory lined shell containing a sand bed fluidised during operation by air through a distributor plate below the bed. The temperature of the bed is controlled at about 750 °C. FBFs fall into two categories : bubbling and circulating. They are based on the same principle, but in the circulating bed unit a higher fluidisation velocity creates very intensive mixing of air and fuel. Particles are carried out of the vertical combustion chamber by the flue gas and are removed in a cyclone to be returned to the FBF through a loop seal. A cross section of a bubbling FBF is shown in Figure 2. Typical design parameters of a bubbling FBFs, which are much more common than circulating types, are reported in Table A.5.