SNAP CODE: **090205**

SOURCE ACTIVITY TITLE: **WASTE INCINERATION**
Incineration of Sludges from Water Treatment

NOSE CODE: **109.03.03**

NFR CODE: **6 C**

1 ACTIVITIES INCLUDED

This chapter includes the volume reduction, by combustion, of sludge resulting from municipal waste water treatment (sewage). Principally this section includes the emissions from chimneys and duct work but not the fugitive emissions from residue handling.

2 CONTRIBUTION TO TOTAL EMISSIONS

The number and throughput of sewage sludge incinerators are small and hence they are rarely a significant source of pollutants except on a local scale. Emissions estimates from incineration of sludges from water treatment as reported in the CORINAIR90 inventory are less than 0.1%.

In the UK dioxin emissions from sewage sludge incineration are likely to contribute up to 0.6% of the total UK dioxin emissions at present.

3 GENERAL

3.1 Description

Sewage sludge arises from two principal sources (HMIP 1992):

- The removal of solids from raw sewage. This primary sludge has a solids content of about 5% and consists of both organic and inorganic substances.
- The removal by settlement of solids produced during biological treatment processes i.e. surplus activated sludge and human sludge. This is known as secondary sludge.

Sewage sludge is incinerated to reduce its volume to lower disposal costs and, in some instances, to recover energy from its combustion either for heating or electricity generation.

3.2 Definitions

3.3 Techniques

At all operational plants the wet sludge is de-watered prior to incineration (HMIP 1992). Several dewatering processes are available; centrifuges, belt or plate presses.

There are three main designs of furnace used for sludge incineration; rotary kiln, fluidised bed and multiple hearth. However the principal influence on the emission factors applicable to a plant is the degree of pollution abatement equipment fitted to the plant.
Virtually any material, that can be burned, can be combined with sludge in a co-incineration process. Common materials for co-combustion are coal, municipal solid waste (MSW), wood waste and agriculture waste. Thus, municipal or industrial waste can be disposed of while providing a self-sustaining sludge feed, thereby solving two disposal problems. There are two basic approaches to combusting sludge with MSW: use of MSW combustion technology by adding dewatered or dried sludge to the MSW combustion unit, and use of sludge combustion technology by adding processed MSW as a supplemental fuel to the sludge furnace (EPA 1994).

- Fluidised Bed Furnace
  FBC consist of vertically oriented outer shell constructed of steel and lined with refractory. Nozzles (designed to deliver blasts of air) are located at the base of the furnace within a refractory-lined grid. A bed of sand, approximately 0.75 meters thick, rests upon the grid. Two general configurations can be distinguished on the basis of how the fluidising air is injected into the furnace. In the “hot windbox” design the combustion air is first preheated by passing through a heat exchanger where heat is recovered from the hot flue gases. Alternatively, ambient air can be injected directly into the furnace from a cold windbox. Partially dewatered sludge is fed into the lower portion of the furnace. Air injected through the nozzles simultaneously fluidises the bed of hot sand and the incoming sludge. Temperatures of 750 to 925 °C are maintained in the bed. As the sludge burns, fine ash particles are carried out the top of the furnace (EPA 1994).

  A fluidised bed incinerator is a single stage process. Examples of the advantages of fluidised bed incinerators include the disposal of solids, liquids, aqueous waste and gases, and the simplicity of the furnace with no moving parts. Disadvantages include the fact that bed diameters and height are limited by design technology and high levels of dust carryover in the flue gas (HMIP 1992).

- Multiple hearth furnace
  The design principle of a multiple hearth furnace (MHF) is a vertical cylinder. The outer shell is constructed of steel, lined with refractory, and surrounds a series of horizontal refractory hearths. Burners, providing auxiliary heat, are located in the sidewalls of the hearths (EPA 1994).

  Scum may also be fed to one or more hearths of the incinerator. Scum is the material that floats on wastewater. It is generally composed of vegetable and mineral oils, grease, hair, waxes, fats, and other materials that will float. Quantities of scum are generally small compared to those of other wastewater solids (EPA 1994).

  Under normal operating condition, 50 to 100 % excess air must be added to a MHF in order to ensure complete combustion of the sludge. Besides enhancing contact between fuel and oxygen in the furnace, these relatively high rates of excess air are necessary to compensate for normal variations in both the organic characteristics of the sludge feed and the rate at which it enters the incinerator. When an inadequate amount of excess air is available, only partial oxidation of the carbon will occur, with a resultant increase in emissions of carbon monoxide, soot, and hydrocarbons. Too much excess air, on the other hand, can cause increased entrainment of particulate and unnecessarily high auxiliary fuel consumption (EPA 1994).

MHF may be operated with an afterburner. The advantages of multiple hearth furnace incinerators include the fact that the retention and residence time is higher for low volatility materials than in other types of incinerator, the handling of high water content wastes and of a wide range of wastes with different chemical and physical properties. Disadvantages include the fact that, due to the longer residence times of the waste materials, temperature response throughout the incinerator when the burners are adjusted is usually very slow, variations in feed can alter the temperature profile and thus the positions of the zones, and difficulties in achieving complete oxidation of volatile organic materials placing an additional load on an afterburner can occur (HMIP 1992).

- Other kiln types
  Rotary kilns are used for small capacity applications. The kiln is inclined slightly with the upper end receiving both the sludge feed and the combustion air. A burner is located at the lower end of the kiln (EPA 1994).

  Electric infrared incinerators consist of a horizontally oriented, insulated furnace. A woven wire belt conveyor extends the length of the furnace and infrared heating elements are located in the roof above the conveyor belt. Combustion air is preheated by the flue gases and is injected into the discharge end of the furnace. Electric infrared incinerators consist of a number of prefabricated modules, which can be linked together to provide the necessary furnace length (EPA 1994). The use of electric infrared furnaces is not so common (EPA 1995).

  The cyclonic reactor is designed for small capacity applications. It is constructed of a vertical cylindrical chamber that is lined with refractory. Preheated combustion air is introduced into the chamber tangentially at high velocities. The sludge is sprayed radially towards the hot refractory walls (EPA 1994).

The wet oxidation process is not strictly one of incineration; it instead utilises oxidation at elevated temperature and pressure in the presence of water (flameless combustion). Thickened sludge, at about 6 % solids, is first ground and mixed with a stoichiometric amount of compressed air. The slurry is then pressurised. The mixture is then circulated through a series of heat exchangers before entering a pressurised reactor. The temperature of the reactor is held between 175 and 315 °C. Steam is usually used for auxiliary heat. Off-gases must be treated to eliminate odours: wet scrubbing, afterburning or carbon absorption may be used (EPA 1994).

3.3.1 Abatement Equipment

The options available for acid gas removal include spray drying and wet or dry scrubbing. Where the emission levels of nitrogen oxides are high, due to the design of the incinerator or because of co-incineration of wastes, urea can be injected into the flue gases to reduce oxides of nitrogen levels by about 30 % (HMIP 1992).

The exhaust gases of the furnaces containing volatile compounds are taken through an afterburner or similar combustion chamber to ensure complete combustion of residual organic material in the vent gas, and to prevent the emission of smoke and odour (HMIP 1992).

As there is the possibility of the formation of dioxins/furans, between 200 and 450 °C, it is important that when gases are cooled it is done as rapidly as possible through this critical temperature range. Such cooling may be accomplished by the use of a heat exchanger/waste heat boiler (of special design) or water spray cooling (HMIP 1992).

In general, older plants have particle arrestment, frequently using an electrostatic precipitator. This will abate the emissions of heavy metal species but may increase dioxin emissions. Modern plant or older plant which have been updated, have a range of different emission abatement equipment which addresses the three main environmental impacts of sewage sludge incineration; acid gas, heavy metal and dioxin emissions.

Typical units fitted include fabric filters, wet scrubbers, lime slurry spray dryer towers, carbon injection with the lime to control mercury and dioxins and activated carbon or coke beds.

3.4 Emissions

Pollutants released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and methane (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2) and nitrous oxide (N_2O). According to CORINAIR90 no main relevant pollutant can be separated (see also Table 1), due to the low contribution of incineration plants of sludge from waste treatment to total emissions.

However, sewage sludge incinerators potentially emit significant quantities of pollutants on a local basis. Major pollutants emitted are: particulate matter, metals, CO, NO_x, SO_2, and unburned hydrocarbons. Partial combustion of sludge can result in emissions of intermediate products of incomplete combustion, including toxic organic compounds such as dioxins (EPA 1994, 1984, 1979, 1982).

Nitrogen and sulphur oxide emissions are primarily the result of oxidation of nitrogen and sulphur in the sludge. Therefore, these emissions can vary greatly based on local and seasonal sewage characteristics (EPA 1995).

Emissions of volatile organic compounds also vary greatly with incinerator type and operation. Incinerators with countercurrent air flow such as multiple hearth designs provide the greatest opportunity for unburned hydrocarbons to be emitted (EPA 1995).

Carbon monoxide is formed when available oxygen is insufficient for complete combustion or when excess air levels are too high, resulting in lower combustion temperatures (EPA 1995).
Polycyclic organic matter emissions from sewage sludge incineration potentially originate from the combustion of carbonaceous material in the sludge, from the combustion POM precursors that may exist in the sludge, and from the combustion of supplemental incinerator fuel (typically natural gas or fuel oil) (EPA 1994).

4 SIMPLER METHODOLOGY

The simpler methodology relies on the use of a single emission factor for each pollutant species combined with a national sludge incineration statistic.

5 DETAILED METHODOLOGY

The detailed methodology involves the use of plant-specific emission factors calculated from emission measurement programmes and plant-specific throughput information obtained from each plant.

6 RELEVANT ACTIVITY STATISTICS

For the simpler methodology the national annual incineration of sewage sludge is required.
The more detailed method requires plant-specific waste throughput obtained from the operators.

If neither of these values are available the mass burn rate of each incinerator should be multiplied by an estimated operating time.

7 POINT SOURCE CRITERIA

The number of sewage sludge incinerators is small so that they may be treated as point sources if plant specific data are available.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

Table 2 contains sludge-related emission factors for incineration of sludge from waste treatment based on CORINAIR90 data in g/GJ. Technique-related emission factors, mostly given in other units (e.g. g/Mg product), are listed in footnotes. The lower heating value depends strongly on the composition of sludge and the content of water: At this stage no data are available for an appropriate definition of a range of lower heating values within the literature.

Table 2: Emission factors for incineration of sludge from waste treatment

			Emission factors						
	Fuel	NAPFUE-code	SO_2 [2] [g/GJ]	NO_x [3] [g/GJ]	NMVOC [4] [g/GJ]	CH_4 [5] [g/GJ]	CO [6] [g/GJ]	CO_2 [kg/GJ]	N_2O [7] [g/GJ]
s	sewage sludge	118	1,300[1]	2,000[1]	8[1]	150[1]	300[1]	820[1]	60[1]
-	not specified	-	100 - 4,000[1]	30 - 5,500[1]	20 - 450[1]	30 - 665[1]	400 - 360.000[1]	660[1]	30 - 400[1]

[1] CORINAIR90 data, area sources (preliminary data)

[2]	SO_x (EPA 1995)	14	kg/Mg	Uncontrolled
		2.8	kg/Mg	Cyclone, controlled
		0.32	kg/Mg	Impingement, controlled
		2.3	kg/Mg	Venturi, controlled
		0.1	kg/Mg	Venturi / impingement, controlled
[3]	NO_x(EPA 1995)	2.5	kg/Mg	Uncontrolled
[4]	NMVOC	0.84	kg/Mg	Uncontrolled
	(EPA 1995)	1.5	kg/Mg	Cyclone, controlled
		0.22	kg/Mg	Cyclone / venturi, controlled
		0.78	kg/Mg	Impingement, controlled
[5]	CH_4	0.39	kg/Mg	Impingement
	(EPA 1995)	3.2	kg/Mg	Venturi
[6]	CO (EPA 1995)	15.5	kg/Mg	Uncontrolled
[7]	N_2O	227	g/t waste	rotary grate (combustion temperature 750 °C)
	(De Soete 1993)	580 - 1,528	g/t waste	Fluidised bed combustion (combustion temperature 770 - 812 °C)
		684 - 1,508	g/t waste	Fluidised bed combustion (combustion temperature 838 - 854 °C)
		275 - 886	g/t waste	Fluidised bed combustion (combustion temperature 834 - 844 °C)
		101 - 307	g/t waste	Fluidised bed combustion (combustion temperature 853 - 887 °C)

In addition, emission factors for HCl, some heavy metals, and dioxins have been derived (Table 3). The range represents emission factors from modern advanced sewage sludge incinerators through to plant with only particle emission abatement equipment.

Table 3 Typical Emission Factors for Plant with only particle emission abatement equipment

Pollutant	Emission Factor g/te waste burnt	Quality Code	Reference
HCl	10 - 450	E	Leonard 1992 Mitchell 1992
Pb	0.001 - 1.8	E	Leonard 1992 Mitchell 1992
Cu	0.004 - 0.5	E	Leonard 1992 Mitchell 1992
Cd	0.9 - 1.3	E	Leonard 1992 Mitchell 1992
Cr	0.001 - 0.07	E	Leonard 1992 Mitchell 1992
Ni	0.001 - 0.07	E	Leonard 1992 Mitchell 1992
Hg	0.4 - 0.6	E	Leonard 1992 Mitchell 1992
Dioxins ug I-TEQ/te	5 - 120	E	Vereniging Lucht 1991

9 SPECIES PROFILES

The dioxin profile for the individual isomers measured to make up the Toxic Equivalence quoted above (Table 3) does not vary in overall shape between most combustion samples. The octa chlorinated dioxins and furans dominate the profile.

10 UNCERTAINTY ESTIMATES

The emission factors given for dioxins are taken from measurements at only two incinerators. Individual measurements demonstrate that the variability in dioxin concentration, at a single plant, can be an order of magnitude between different sampling periods. There were also wide differences noticeable in the emission factors available for other pollutants depending on which of the many combinations of gas cleaning equipment was in use on the plant. Hence any emission factor is subject to an uncertainty considerably greater than 100%.

The emission factors for pollutants in Table 2 are based on CORINAIR90 data and the wide range in results indicates the significant variability between sources and the uncertainty in the derivation of emission factors.

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The emission factors provided in Table 2 are related to point sources and area sources without specification. CORINAIR90 data can only be used in order to give a range of emission factors with respect to point and area sources. The emission factors are unlikely to be typical of all European sewage sludge incinerators. Further work is required to develop emission factors, including technical or fuel dependent explanations concerning emission factor ranges.

No information is available on the fugitive emissions of heavy metals and dioxins associated with residue handling and disposal. This may represent a significant proportion of the total emission especially where advanced abatement equipment is fitted to an older plant.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

All sources should be considered point sources if possible. Otherwise disaggregation should be done on the basis of population or number of plants per territorial unit.

13 TEMPORAL DISAGGREGATION CRITERIA

The large incinerators operate as continuously as possible and should be treated as 24 hour 7 days a week emitters. The smaller plant less than 5 tonne per hour should be treated as 8 hour 5 days a week processes unless information available suggests otherwise.

14 ADDITIONAL COMMENTS

15 SUPPLEMENTARY DOCUMENTS

16 VERIFICATION PROCEDURES

Verification is through comparison with emission estimates from other countries together with a measurement programme for selected sites except for trace organics as residual historical soil levels may greatly influence present day air concentrations.

17 REFERENCES

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17.1 List of abbreviations

FBC	fluidized-bed combustion
MSW	municipal solid waste
MHF	multiple hearth furnace
POM	persistent organic matter

18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE AND SOURCE

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