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Review

Recycling and recovery routes for incinerated sewage sludge ash (ISSA): A review

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ABSTRACT

The drivers for increasing incineration of sewage sludge and the characteristics of the resulting incinerated sewage sludge ash (ISSA) are reviewed. It is estimated that approximately 1.7 million tonnes of ISSA are produced annually world-wide and is likely to increase in the future. Although most ISSA is currently landfilled, various options have been investigated that allow recycling and beneficial resource recovery. These include the use of ISSA as a substitute for clay in sintered bricks, tiles and pavers, and as a raw material for the manufacture of lightweight aggregate. ISSA has also been used to form high density glass–ceramics. Significant research has investigated the potential use of ISSA in blended cements for use in mortars and concrete, and as a raw material for the production of Portland cement. However, all these applications represent a loss of the valuable phosphate content in ISSA, which is typically comparable to that of a low grade phosphate ore. ISSA has significant potential to be used as a secondary source of phosphate for the production of fertilisers and phosphoric acid. Resource efficient approaches to recycling will increasingly require phosphate recovery from ISSA, with the remaining residual fraction also considered a useful material, and therefore further research is required in this area.

Contents

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1. Introduction

1.1. Sewage sludge disposal practices in the EU

The application of sewage sludge to agricultural land is generally considered to be the "Best Practical Environmental Option" because the N, P and K content of sludge provides high fertiliser value and the organic matter acts as a useful soil conditioner. However, a number of factors are making land-spreading of sewage sludge increasingly difficult. For example, the transport time and distances between utilities producing sludge and suitable agricultural land are generally increasing and this is increasing costs. While sludge disposal to land is regulated by the EU Sludge Directive (86/278/EC), many countries have applied tighter limits because of public concerns associated with pathogen transfer to crops and the accumulation of heavy metals in agricultural soils. For example, in the UK a voluntary code of conduct known as the "Safe Sludge Matrix" has been introduced and this only permits limited application of pre-treated sewage sludge under specific conditions (ADAS, 2001). However, it should also be noted that sewage sludge is exempt from controls and charges for the land disposal of other wastes levied via the UK Environmental Permitting scheme. In the Netherlands, the Flemish region of Belgium and regions of Germany that have sandy soils, land-spreading has effectively been banned due to the adoption of prohibitively restrictive heavy metal limits for sewage sludge and sludge treated soils (Milieu et al., 2010). In other countries such as Greece, Italy, Malta and Iceland, landfill remains the major disposal route for sewage sludge. This will become difficult to justify in the EU as the EU Landfill Directive (99/31/EC) places increasing restrictions on the quantities of biodegradable waste that can be landfilled due to concerns over methane generation under anaerobic conditions. An alternative to these options was sea disposal of sewage sludge but this has been banned in EU countries since 1999 following the implementation of the EU Urban Wastewater Treatment Directive (1991). The differences in current sewage sludge disposal practices in EU countries from data available via Eurostat are shown in Fig. 1.

The major alternative to land-spreading and landfill are thermal treatment processes. It can clearly be seen from Fig. 1 that the countries with low levels of land-spreading have invested significantly in incineration. An important advantage of incineration is the degree of control this provides to sewage sludge managers.

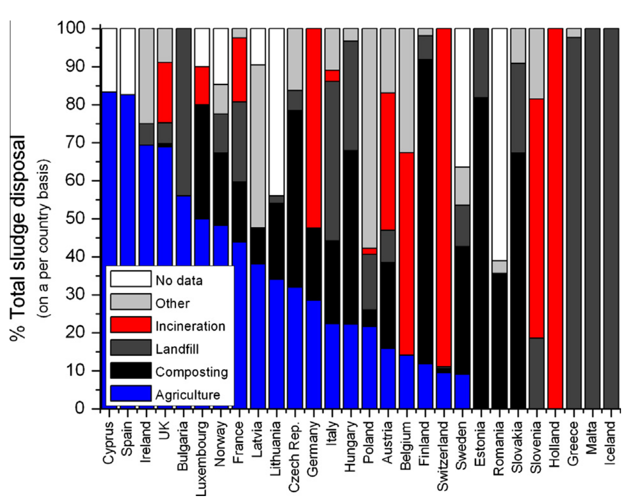

Fig. 1. Sewage sludge disposal management practices in EU countries in 2009 or in the year of latest available data on Eurostat. Data expressed as % of total sludge mass produced in each country. Note that data for Portugal and Denmark was not available.

Poor weather, changes in landowner attitudes and unexpected occurrences such as the foot and mouth disease outbreak in the UK in 2001 can have a dramatic effect on land disposal capacity. Such impacts do not normally affect sewage sludge disposal using thermal treatment technologies. For an excellent review of thermal treatment options of sewage sludge the reader is directed to work by Werther and Ogada (1999) and Fytili and Zabaniotou (2008).

Outside of the EU, there is a long history of sewage sludge incineration in the USA and Japan. Densely populated regions such as those in Japan have the double problem of high quantities of sludge production and low land availability. The largest sewage sludge incineration plant in the world is currently under construction in Hong Kong and is expected to produce around 240,000 tonnes of ISSA per year from 2013 onwards.

1.2. Mono-combustion of sewage sludge

During incineration, organic matter is combusted to CO_2 and other trace gases, with water removed as vapour. The process cannot be considered as a complete disposal option because significant quantities of inorganic incinerated sewage sludge ash (ISSA) remain. This is removed from flue gases and requires further management.

This paper focuses on the ISSA generated by conventional mono-combustion of sewage sludge. Although there are some examples of co-combustion of sewage sludge with coal (Ireland et al., 2004; Leckner et al., 2004; Wolski et al., 2004), there are important legal issues that need to be overcome involving both the definition of sewage sludge as a waste or fuel and standards for the use of subsequent co-combustion ashes (Cenni et al., 2001; EN 197-1). These issues also apply to ISSA despite the fact that mono-combustion of sewage sludge has been widely practised at an industrial scale in many dedicated plants across the world over several decades (Werther and Ogada, 1999).

An overview of a typical modern fluidised bed sewage sludge mono-combustion process is given in Fig. 2. Primary and secondary sewage sludge typically consists of 1–4 wt.% solids and this is pumped to tanks for further treatment. Fig. 2 shows a thickening stage where sludge settles and the supernatant is removed. This raises the solids content to 3–8 wt.% solids. Thickened sludge is then dewatered typically using plate or belt presses. At this stage organic or inorganic additives can be employed to improve dewatering. For incineration there is an obvious incentive to optimise dewatering using organic additives as there are dual advantages of improving sludge calorific value and reducing inorganic ash content. The solids content of dewatered sludge typically varies from 18 to 35 wt.%.

Although the calorific value of sewage sludge is often regarded as similar to that of brown coal, this is somewhat misleading. The calorific value of the solid organic matter present in sewage sludge does have similar calorific value to brown coal, but when sewage sludge is considered as a potential fuel, consideration has to be given to the accompanying inorganic solids, which have no calorific value. In addition, the water content consumes heat as it is vapourised. Sewage sludge typically has to be at least 28–33 wt.% solids to burn auto-thermically, with no requirement for external fuel to maintain the incineration process. Some researchers have examined the combustion of sewage sludge with significantly higher solids content, with the aim of minimising supplementary fuel requirements (Sanger et al., 2001). However, any gain in energy output must be balanced against the energy input required for drying the feed sludge to higher solids content.

Sludge and hot compressed air (ca. 500–600 °C) are fed to the combustion chamber. The sand bed temperature is typically 750 °C and the overhead freeboard zone at 800–900 °C. Guidance on good operation is provided by technical documents (PD CEN,