REUSE OF SEWAGE SLUDGE AS RAW MATERIAL OF PORTLAND CEMENT IN JAPAN

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ABSTRACT

A potential alternative of sewage sludge reuse is the substitute of raw material for Portland cement. This paper overviews Japanese implementation of this and discuss the best selection of pretreatment for this purpose. The pretreatment includes dewatering, incineration, and lime treatment.

KEY WORDS

Abstract; CO_2, Dewatering, Incineration, NOx, Portland Cement, Reuse,

INTRODUCTION

In the past, a main way of a sewage sludge reuse was an application to green fields and agricultural lands as in Europe and America. In the era, "composting" was widely implemented for the purpose. On the other hand, Japan's society had great concerns on soil contamination of heavy metals, having experienced loss of many lives caused by Minamata mercury and ITAIITAI cadmium diseases in 1960s. The land application has not been widely implemented. Accordingly, the composted sewage sludge accounts for as low as a quarter of the total recycled rate of 60% (15% of the total sewage sludge).

Because of large volume, the sludge generated in big cities is incinerated or melted. The resultant ash or slag is used as backfill for civil engineering works, raw material of bricks and tiles, etc. The production cost of the ash origin bricks is more than doubled compared with that of traditional ones.

In general, the supply of the sewage brick exceeds the demand, which results in an increasing stock pile. Due to the reason, the public service personnel have been compelled into using the bricks for public works projects.

An alternative destination of sewage sludge was developed. It is a plant of Portland cement. It is reused for raw material of Portland cement. An amount of sewage sludge accepted by existing Portland cement plants has shown a rapid increase in the last few years as shown in Figure 1. At present, an amount of the sludge for the purpose is more than 20 % of the total in Japan in 2000.

In this paper, the authors discuss the methods of supplying sewage sludge to Portland cement plants, including pretreatment (incineration or dewatering), reduction of nitrogen oxide (NOx) emissions from the Portland cement manufacturing process. In addition, the whole process is evaluated by LCA.

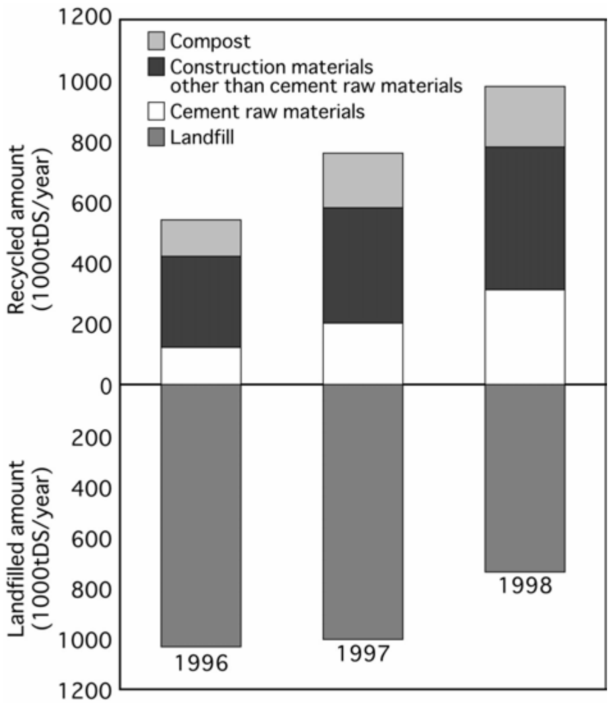


Fig 1. Recycled and Landfilled Amounts of Sewage Sludge in Japan

METHODS OF APPLYING SEWAGE SLUDGE TO PORTLAND CEMENT PLANTS AS RAW MATERIAL

The modern Portland cement plant is generally composed of three processes as shown in Figure 2 [1)3)]. They include 1) the raw materials grinding process where raw materials such as limestone, clay, silica sand, and iron ore are dried and ground, 2) the burning process where the ground raw materials are pyroprocessed at approximately 1450 ℃ in a coal-fired kiln to produce clinker, an intermediate product, and 3) the finishing process where a clinker-gypsum mixture is ground to be Portland cement.

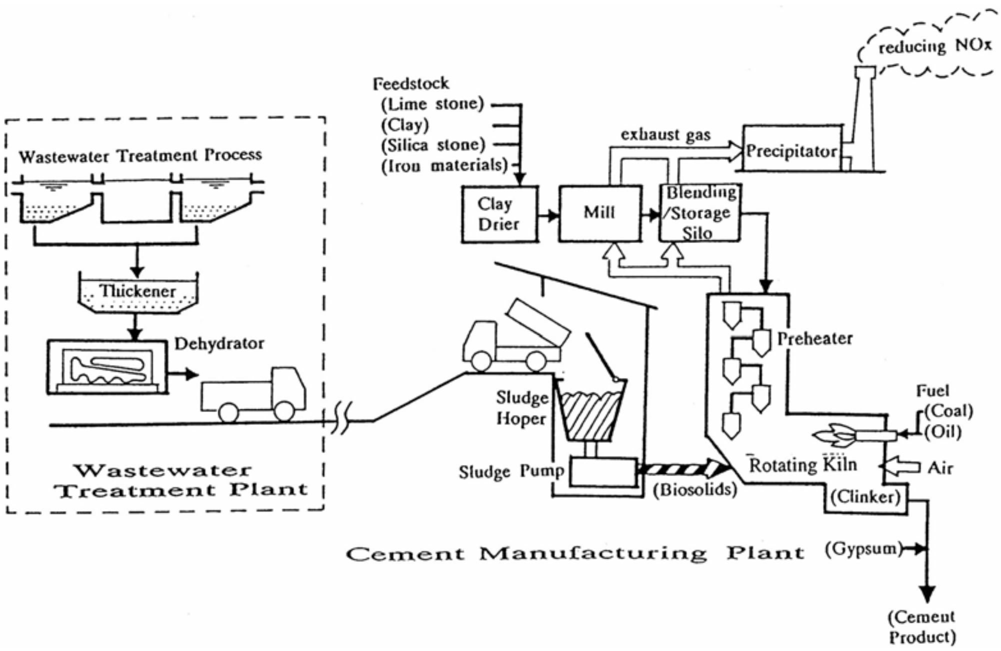


Fig 2. Portland Cement Manufacturing Processes and Direct Injection of Dewatered Sludge (Biosolids)

Pretreatment methods implemented in Japan are shown in Figure 3.

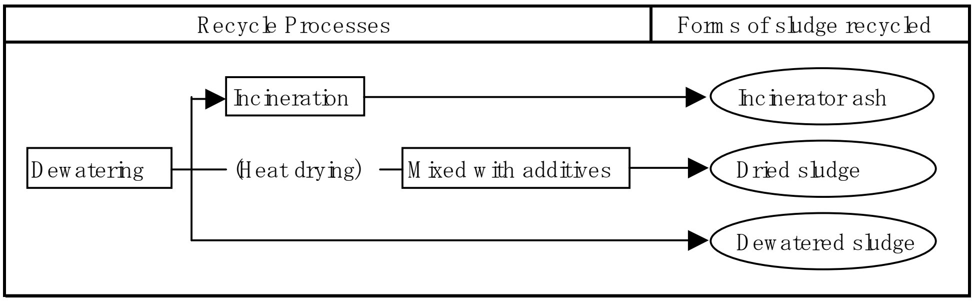


Fig 3. Pretreatment of Sewage Sludge Before Supplying

Sludge cake

Composition of incinerated ash is similar to that of clay as shown in Table 1. It is supplied as a substitute for clay in the raw materials. Dewatered sludge is injected into the kiln directly or sometimes blended with waste oil.

Table 1. Composition of Dewatered Sludge (Biosolids) and Clay [1)2)]

(%)

	Water	Solid	Components of the solids							
			Organic matter	SiO_2	Al_2O_3	Fe_2O_3	CaO	P_2O_5	Cl	calorie/g
Biosolids	80	20	63	32.4	15.6	13.4	8.5	15.7	0.04	4,500
Dried powder of biosolids	5	95	38	1.9	0.3	0.3	58.0	0.45	0.01	2,250
Clay	15	85	–	63.3	18.6	6.0	0.4	–	–	–

Today in Japan, a rate of application of dewatered sludge is more than a half of the total used as a Portland cement raw material (approximately one million tons on a dewatered sludge basis). Its merit is no initial investment requirement, which boosts this application.

However, dewatered sludge is more costly to transport due to a larger volume than incinerator ash. It has potential risk of draining from sludge conveying trucks, as well as bad odors. Therefore, a specific attention should be paid to prevent the risk.

Drying

Another pretreatment is “drying”. It is implemented in Nara Prefecture government [1)]. Nara Prefecture tries to convert sewage sludge into dried sludge powder with less than a few per cent of moisture and with a far smaller volume, enabling freight and odor to be cut. The dewatered sludge is blended with quicklime, usable as a cement raw material, which dries up the sludge with heat generated by the following hydration reaction.

$$CaO + H_2O \rightarrow Ca(OH)_2 + 15.33 \text{ kcal/mol}$$

The product, called dried powder sludge, is sterilized, very low in moisture content and odorless. It can then be utilized as a raw material of Portland cement and fuel at the same time.

The flow sheet of the facilities is shown in the Figure 4 [2)]. Dewatered sludge is blended with quicklime, digested and then made into a dried powder. Waste gas generated from the digesting and blending machine contains dust and ammonia as high as 2,400mg/l. The waste gas is then treated with a bag filter, chemical scrubbing, and activated carbon absorption processes. When the quicklime is blended at a rate of 100%, the sludge of 80% moisture content is converted to the dried sludge of 5% moisture. The yield rate of the dried sludge is 167% of the dewatered sludge. The dried sludge includes particles of approximately 100 to 200μ m in an average diameter. It is low in fluidity, and very good jettability. Its composition is shown in Table 1. It can be stored for more than 10 days. It includes 40% volatile solids and 60% lime usable as fuel and raw material as well.

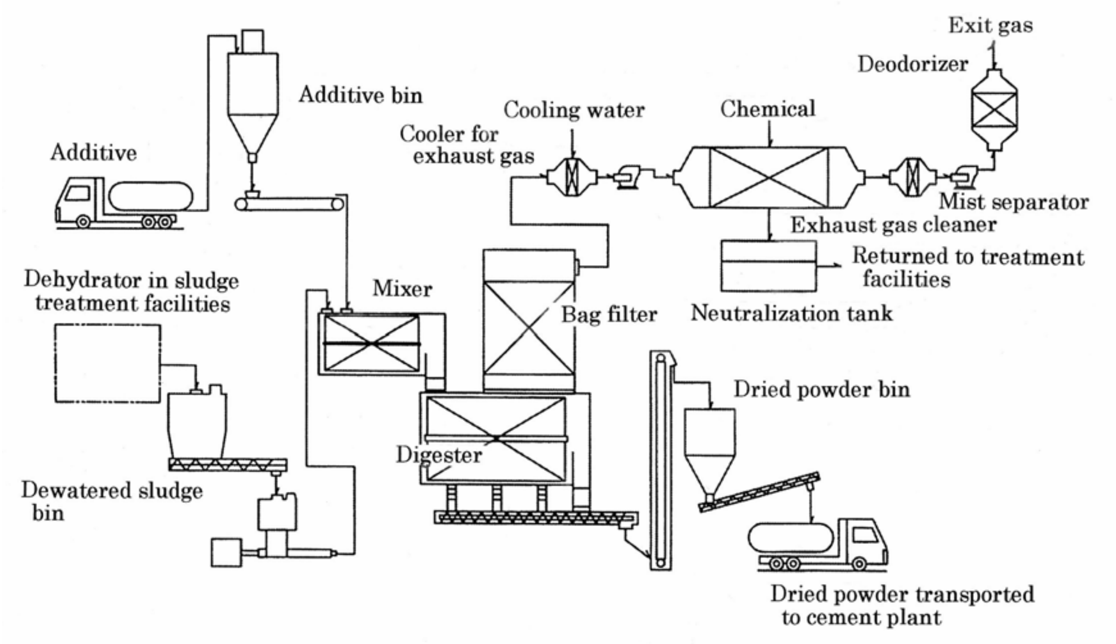


Fig 4. Flow Sheet of Dried Powder Sludge Manufacturing Facilities

ENVIRONMENTAL ASSESSMENT OF RECYCLING DEWATERED SLUDGE AS RAW MATERIAL OF PORTLAND CEMENT

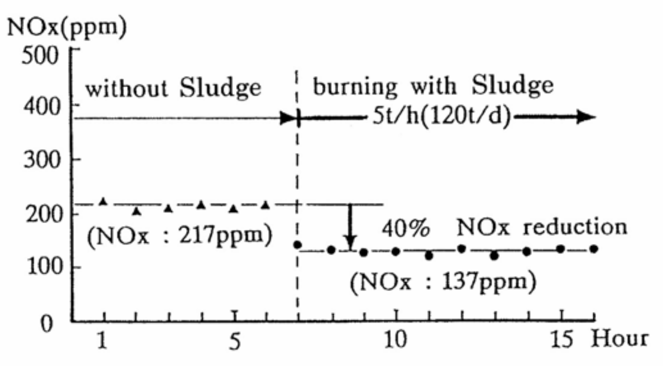
Denitrification of exhaust gas from kiln

A rotary kiln in which raw materials are sintered at temperatures of 1,450℃ emits a rather large volume of NOx gas. When dewatered sludge is injected into the kiln, ammonia contained in the dewatered sludge decomposes nitrogen oxides as follows:

$$2\ NH_3 + 2\ NO + 1/2\ O_2 \rightarrow 2\ N_2 + 3\ H2O$$

The Figure 5. shows an example of NOx emission from a kiln of a Portland cement manufacturer where dewatered sludge is injected. It is seen that the sludge cake can reduce 40% of the NOx.

Fig 5. Change in NOx Emission



Carbon dioxide

From a view of CO_2 emissions, the two applications of sludge cake and incinerated ash are compared under the conditions shown in Table 2. The transport distance is assumed 50 km for both the applications.

Table 2. Conditions for Calculations

Transporting of incinerator ash and dewatered sludge	Distance (km)	50
	Fuel usage (liters-LO/t)	4
Processing of dewatered sludge at cement plant	Cement kiln capacity (t-cli/d)	2,500
	Processed amount (t-DS/d)	30
	Increase in power (kWH/t-DS)	12.5
	Increase in heat (Mcal/t-DS)	125
Incinerating at incineration facilities	Power usage (kWH/t-DS)	82
	Fuel usage (liters-AHO/t-DS)	21
Specific CO_2 generation	Light oil (kg-CO2/liter)	2.65
	Power (kg-CO2/kWH)	0.357
	Coal (kg-CO2/Mcal)	0.37
	A-Heavy oil (kg-CO2/liter)	2.77

*) LO: Light oil, DS: Dewatered sludge, AHO: A-Heavy oil

An amount of CO_2 gas generated in the case of direct injection of dewatered sludge into cement kiln, kg-CO_2/t-dewatered sludge:

CO_2 Generated by Transporting Sludge	11kg
Increase in CO_2 from a Rise in Electric Power	4kg
Increased CO_2 from a Rise in Fuel	46kg
Total	61kg

CO_2 gas generated in case of incineration at a sewage treatment plant and supplying the ash as a Portland cement raw material, kg-CO2/t-dewatered sludge:

CO_2 Generated by Consuming Electric Power	29kg
CO_2 Generated by Consuming Fuel	58kg
CO_2 Generated by Transporting Ash	1kg
Total	88kg

These figures show, for a cement kiln of an average size and the given amount of sludge, that the method of direct injection of dewatered sludge into the kiln is 30 % less of CO_2 emission compared to the ash. It must be noted that the comparison is made just under the above conditions, being that the greater the volume of the sludge injected into the kiln, the larger the amount of fuel and electric power consumed at the Portland cement plant. This rise can be attributed to a high water content of the sludge and characteristics of Portland cement manufacturing processes.

CONCLUSION

As various technologies for reuse of sewage sludge have been developed and put into operation, a recycling rate has increased rapidly. Noticeable is the rise in use as a Portland cement raw material. Three methods have mainly been implemented for the purpose. They include incinerator ash, dewatered sludge, and dried powder sludge. Among the three, the method of directly injecting dewatered sludge into Portland cement kilns seems to be the most attractive, and actually, the amount processed by such a method is growing rapidly. This tendency can be attributed to advantages that the method neither requires to construct incinerators nor generates additional running cost for them.

Direct injection into kilns (demonstrated by operational results at K city in Japan) proves that the NOx concentration in kiln exhaust gas was reduced by 40%. Moreover, the author's calculations suggest that CO_2 generation decreases by 30%, as compared with the case of using incinerated ash. In the near future, direct supply of dewatered sludge to existing Portland cement plants will become one of the leading methods for reuse of sewage sludge in Japan.

<References>

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