EFFICIENT DRYING OF SLUDGES

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ABSTRACT

Discharges of chlorinated organic compounds from bleached kraft pulp mills are expected to be limited to less than 1.5 kg AOX/t in the near future. Some of the chlorinated organics not eliminated through process modifications could be "trapped" on sludge from the external treatment process(es).

The disposal of pulp and paper mill sludges, which may contain chlorinated organic compounds, represents an increasing problem. However, if these sludges could be dried to 90% dry content, in an energy-efficient manner, they could provide high enough flame temperatures upon combustion in order to destroy the organic chlorides entrapped in the sludges. In addition, this approach could improve a mill's fuel self-sufficiency.

A novel drying process for pulp and paper mill sludges investigated at the Institute indicated the potential to provide the above dryness criterion, with the promise of advantages over existing drying technologies.

DISCUSSION

In recent years, combined mill sludges have become more difficult to dewater as biological solids, generated in wastewater treatment, have become more common. At the same time, the options for sludge disposal have become more limited, and the options that remain for many mills require the economic production of dryer sludge cakes. More specifically, increasing numbers of mills are searching for ways to (a) reduce the costs associated with sludge hauling, (b) get maximum use out of existing landfill space, and (c) make sludge a more attractive fuel for combination-fuel-fired boilers. These considerations have created a growing interest among pulp and paper companies in sludge dewatering technologies capable of producing dryer cakes at a reasonable cost.

Mechanical dewatering methods have been shown to be rarely able to reduce the water content of sludges below 60% (wet basis); this limit is significantly higher for secondary or primary + secondary sludges.

Because of this, efficient drying techniques are being investigated for their applicability to economically achieve any desired sludge dryness.

Sludge Drying

The sludge drying systems in use vary considerably. One mill has installed a dedicated, gas-fired, rotary kiln dryer to dry a particularly wet and difficult-to-dewater waste treatment sludge before burning it in a coal-fired power boiler [1]. Several other mills have used gas or oil-fired air entrained dryers for sludge drying [2]. Another mill's sludge undergoes a degree of drying as it is conveyed by boiler flue gas through a pneumatic hog-fuel transport system. Other drying alternatives also exist. For instance, several wood fuel drying systems presently being marketed demonstrate the ability to handle certain bark/sludge combinations. For a detailed description of systems using flue gas or steam directly for drying biomass, the reader is referred to a comprehensive report by MacCullum et al [3].

The Carver-Greenfield process [4,5] combines multi-effect or mechanical vapour recompression evaporation with the use of a fluidizing carrier oil. The material to be dewatered is fluidized, i.e., suspended in oil, by mixing it with 3 to 13 parts of carrier oil for each part of dry solids by weight. This highly fluid mix is then pumped into the evaporator system. As the water is boiled off and condensed, the carrier oil keeps the solids mixture pumpable. After all water has been evaporated, the bulk carrier oil is separated from the solids.

The ITT Rayonier's Port Angeles, Washington, sulphite market pulp mill was producing 20 t/day animal feed from the effluent of its secondary treatment plant, using a Carver-Greenfield Process [6]. The ITT Rayonier animal feed production system was a two-stage dewatering operation. In the first stage, the biomass (sludge) from the secondary effluent treatment plant was treated with polymers to allow water to drain more easily from the solids. The conditioned sludge was then distributed among five twin-wire belt filters operating in parallel. The moisture content was decreased from 98 to 88%. The press filtrate was returned to the secondary effluent treatment plant. The product cake was then sent to the second stage of the dewatering operation, a Carver-Greenfield multiple effect evaporator system. The ITT Rayonier plant was retired a few years ago due to problems encountered with a steady product supply to customers as a result of low demand for sulphite market pulp.

The Carver-Greenfield process has also found application in other industries such as pharmaceutical plant wastes, dye manufacturing waste streams, primary and secondary sanitary sewage sludge and others.

Weyerhaeuser Co. has developed a dry solids evaporation process to produce discrete black liquor particles of more than 95% solids content [7]. the process is based on the Carver-Greenfield concept and uses oil-flash evaporation. The objective of the dry solids evaporation step in the process is to remove essentially all of the remaining water from the concentrated black liquor coming from the multiple-effect evaporators. The latent heat in the vapour produced in the dry solids evaporator is recovered in the multiple-effect evaporator system or in the concentrator as though an additional effect were added.

A hog-fuel drying process has been proposed by Paprican [8-10] which is similar to the Carver-Greenfield Process. In order to test the process, a continuous hog-fuel drying pilot plant based on the principle of recirculating a hog-fuel/oil suspension through a steam-heated heat exchanger was designed, built and successfully operated. A schematic flow diagram of the pilot plant is shown in Figure 1. The capacity of the pilot plant was approximately 3 kg/h of hog fuel (dry basis).

Prescreening hog fuel was fed from a hopper, via a screw feeder, into a tank which contained recirculated hot crude tall oil. The slurry from this "mixing tank" was then pumped to a vertical, stainless-steel, single-tube heat exchanger. The foamy three-phase slurry, entering the pump, reduced the pumping capacity by 50-85% at oil-hog fuel consistencies of 0.5 to 2.7% (w/w) and water vapour contents of 0.02 to 0.015% (w/w), compared with dry, wood-free oil. The heat exchanger tube (2.5 m long, 0.5 m diameter) was placed in a steam heated jacket. The effective heat transfer area was approximately 0.4 m^2.

The wet hog fuel/oil slurry, with some entrained vapour, entered the bottom of the heat exchanger and left from the top as a partially dried hog fuel/vapour/oil mixture. The evolving vapour disengaged from the slurry in a small tank, was drawn from the system by a fan, condensed, and collected. Vapours were also removed from the settling and mixing tanks.

The dried hog fuel/oil slurry, which left the vapour separator, flowed into a settling tank where the dried and oil-saturated hog fuel particles settled, while those containing significant moisture (± 25%) had a tendency to float, and were therefore recycled to the mixing tank. The particles which settled were removed from the dryer by a simple modified worm screw press without back pressure control which was placed at the bottom of the mixing tank. A continuous flow of oil into the press increased the settling rate of the hog fuel particles. The oil pressed from the hog fuel was also recycled back into the mixing tank.

In some cases, such as deinking mill sludges, the ash contribution to the boiler is significant, and segregation of these materials from the sludge stream becomes important and poses an additional burden on the acceptability of sludge burning in the boiler. The biomass drying process tested and described above could segregate a considerable portion of the inorganic constituents entrained and mixed with the sludge, during fluidization with the heat-transfer oil, and can be separated from the oil.

EXPERIMENTAL

The adoption of the oil drying process described in the previous section for pulp and paper mill primary sludges required filling some gaps in information before a better technical and economic assessment of this approach can be made on the basis of more detailed system and equipment design. The experimental apparatus to carry out the laboratory batch sludge drying tests designed for this purpose is shown in Figure 2. The drying vessel consisted of a 1.2 L stainless steel beaker containing the sludge to be dried suspended in the drying oil (e.g., Bunker C or crude tall oil). The drying vessel was immersed in the oil of a constant temperature bath which maintained the drying temperature at the desired value, viz., 100°C to 150°C.

After drying, the sludge was separated from the drying oil in a stainless steel funnel which acted as a sludge filter. In order to maintain the filtration temperature essentially at the same level as the drying temperature, the hot bath oil was circulated through the stainless steel jacket of the filtration funnel. As soon as the drying test was terminated the drying oil containing the dried sludge was poured into the funnel. Surplus oil was drawn out via the opening at the end of the cone by vacuum.

Batch drying tests were carried out with the experimental apparatus. The data were presented in the form of drying rates, product characteristics and environmental impact of the condensates.

The drying rate was determined by:

$$\text{Drying rate} = \frac{\text{moisture evaporated (g)}}{\text{total drying time (min)}} \cdot \frac{1}{\text{initial moisture (g)}}$$

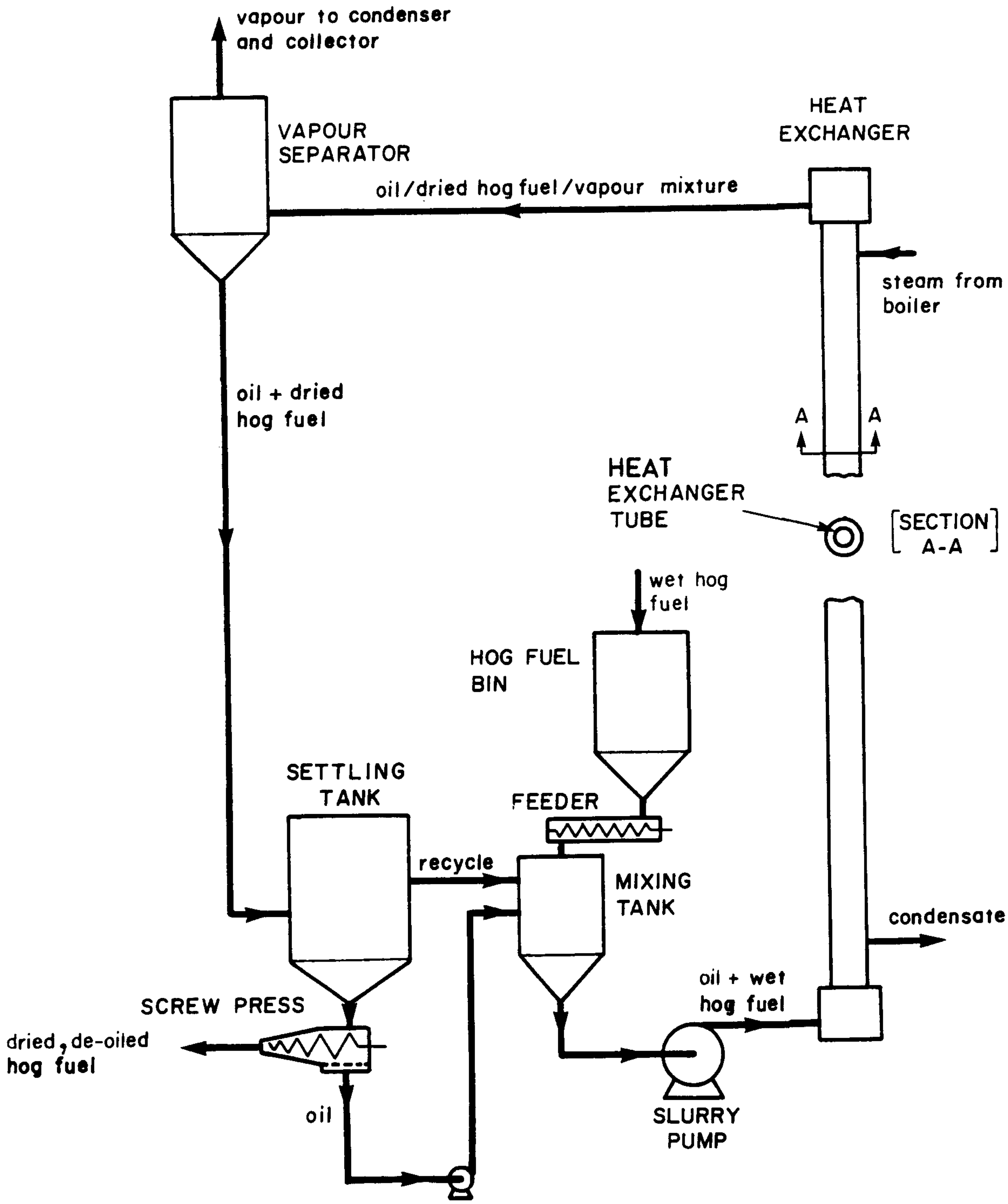

Figure 1. *Schematics of the Paprican hog-fuel drying pilot plant.*

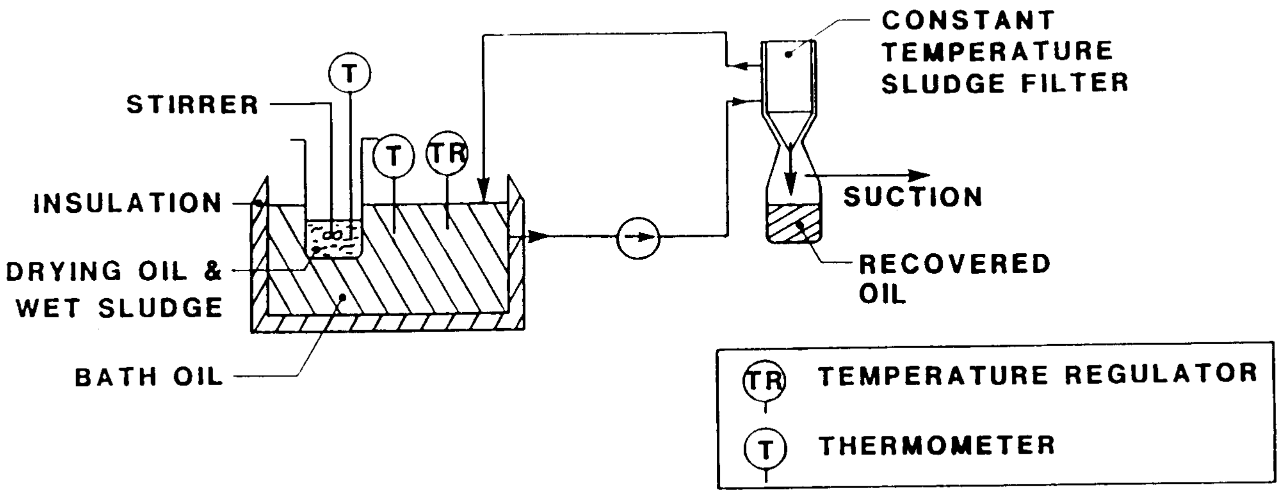

Figure 2. Experimental equipment used for indirect drying of pulp and paper mill sludges.

As an example, the effect of Bunker C and crude tall oil on the drying rate of softwood-based kraft mill primary sludge is shown in Figure 3. The drying rate in tall oil appears to be about 20% higher than in Bunker C oil.

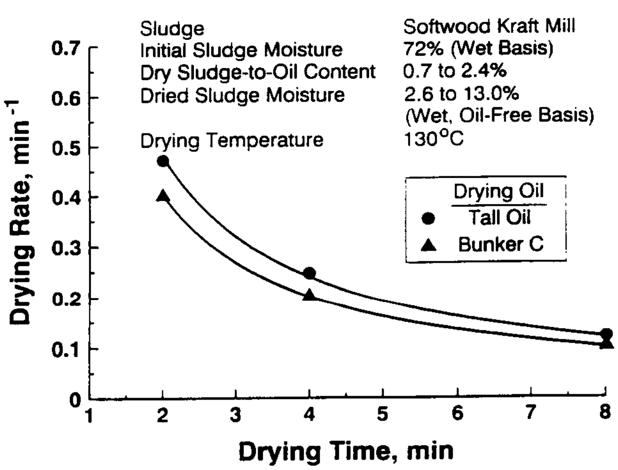

Figure 3. Overall drying rates of softwood kraft mill sludge as a function of drying time and type of oil used.

SUMMARY OF THE RESULTS

The tests with kraft mill and newsprint mill primary sludges indicated that water contents of less than 5% (wet, oil-free basis) could be obtained at high drying rates with drying temperatures of around 110°C. Pressing with a screw press could result in residual oil content of 25 to 30%. The calorific value of the product could be in the range of 25 to 28 MJ/kg, depending on whether crude tall oil or heavy fuel oil is used as drying medium.

The environmental impact on the total mill effluent was assessed by determining the BOD_5, COD, pH and the toxicity of condensates collected during the tests. In the case of a bleached kraft pulp mill sludge, the condensates obtained when drying with either tall oil or Bunker C oil and comparing untreated condensates to biologically treated total mill effluent, the volume would increase by about 0.2%, the BOD_5 load by less than 1% and the toxicity between 2.6 and 4.4%.

In the case of drying sludge from a newsprint mill by using either tall oil or Bunker C oil, the discharge volume would increase by less than 0.2% and, on the same basis as above, the BOD_5 loads and toxicities would increase by 8% and up to 17%.

Based on the continuous and batch drying tests, as described above, a sludge drying process [11] suitable for a kraft mill was conceptually designed and proposed (Figure 4).

Sludge cake which has been dewatered to 20 to 40% consistency using a standard mechanical dewatering device is fed into a fluidizing tank. The fluidizing tank serves as a buffer to smooth out minor variations in both the flow of the feed and the percentage solids in the feed and for mixing the carrier oil with the feed material.

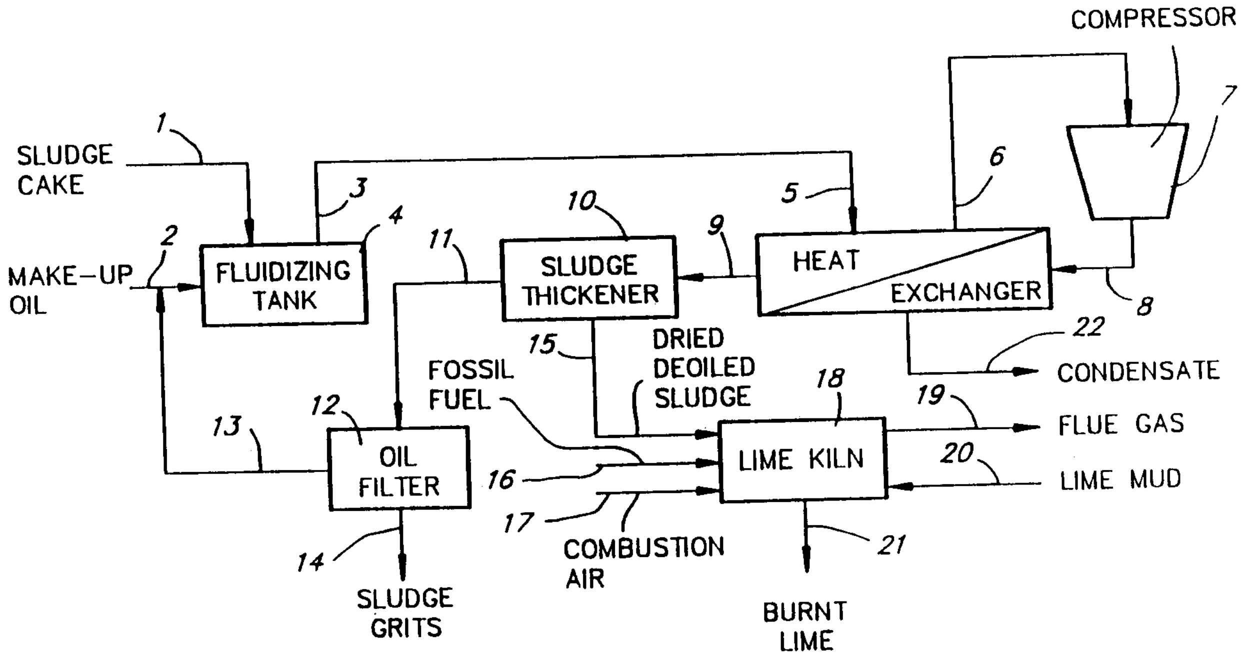

Figure 4. Conceptual flow diagram of sludge drying process.

The fluidized oil/wet sludge mixture is pumped into the heat exchanger of a vapour recompression evaporation system. This process allows the sludge to dry with very high energy efficiencies. The condensed vapour is passed to the mill waste water treatment.

The oil/dried sludge mixture flows into a sludge thickener to separate the dried sludge from the oil. The dried sludge leaving the sludge thickener may contain up to 30% by weight residual oil and can be burned along with fossil fuel in the fired end of the lime kiln. Chlorinated dioxins and furans contained in the dried sludge are destroyed in the lime kiln such that neither the burnt lime nor the flue gas contains any amount of dioxins and furans. The oil separated from the sludge is pumped to a pressurized oil filter to remove inorganic contaminants entrained with the sludge. The cleaned oil is pumped back into the fluidizing tank. The losses of oil with the dried sludge is compensated for by make-up oil into the fluidizing tank. As fluidizing carrier oil, crude tall oil or heavy fuel oil might be used.

An economic analysis based on information provided by the licensee of the Carver-Greenfield Process indicated that for a mill to dry 40 dry tons/day primary sludge, using the above process, would require a total capital investment of about $6 million and the capital and operating cost would be around $47/dry ton after allowance for fuel credit for the sludge and the entrained oil, but no credit against alternative sludge disposal (e.g., landfill) costs. The estimates are based on initial product moisture of 75% (wet basis) and the final product moisture content of 10% (wet, oil-free basis) and an oil content of 25% (dry basis).

CONCLUSIONS

The most appropriate technique to dry high-moisture containing pulp and paper mill sludges to very low (≤ 10%) water content appears to be the technically proven heavy oil version of the Carver-Greenfield Process, operating at drying temperature of up to 115°C.

There are various situations or scenarios under which this sludge drying process might be a valid option. These could be, for example:

1. Sludge disposal costs are substantially higher than $47/dry ton: Assuming 10% after tax profit on the capital investment, the mill's sludge disposal cost for landfill would have to be at least $124/dry ton to justify the investment on strictly economic grounds.

2. Diminishing or non-existence of landfill sites prevails: In this case the option of efficient dewatering of the sludge in order to increase the dryness to 35-40% and relatively inefficient combustion in an existing combination fuel boiler has to be weighed against the oil drying technique.

3. Sludges from bleached kraft mills containing objectionable chlorinated organic compounds have to be disposed of: It may be mandatory to dry these sludges to very high solids contents, e.g., 90%, in order to attain a high enough combustion temperature (e.g., $\geq$1000°C and > 1 sec) in order to destroy the chlorinated organic compounds. Under this scenario the oil drying of sludges can become the most viable option for burning and energy recovery in an existing combustion unit.

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